1978

Simulation and analysis of ammunition transport capability in support of a combat unit

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SIMULATION AND ANALYSIS OF AMMUNITION TRANSPORT CAPABILITY IN SUPPORT OF A COMBAT UNIT

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THESIS

SIMULATION AND ANALYSIS
OF AMMUNITION TRANSPORT CAPABILITY
IN SUPPORT OF A COMBAT UNIT

by

John Richard Kelley

March 1978

Thesis Advisor: S.H. Parry

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UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Simulation and Analysis of Ammunition Transport Capability in Support of a Combat Unit		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis; March 1978
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) John Richard Kelley		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		12. REPORT DATE March 1978
		13. NUMBER OF PAGES 121
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Ammunition Supply Point
Logistics Modelling
Stowed Load
Support Platoon

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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(20. ABSTRACT Continued)

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Simulation and Analysis of Ammunition Transport Capability in Support of a Combat Unit

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
March 1978

ABSTRACT

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I. INTRODUCTION

This thesis presents a simulation of the Support Platoon of a U. S. Army Tank Battalion. The objectives of this study are:

1. to develop a logistics model that may be integrated into a battalion level combat simulation.
2. to estimate transport unit capability in various conflict scenarios by parametric analysis.
3. to evaluate the simultaneous impact of major factors which impact on combat support operations and to quantify their effect.

These objectives outline a substantial goal when considering the dearth of material available on the operations of this particular unit. The reason may be that the Support Platoon is under the direct control of a combat unit and therefore not catalogued in Army manuals with other transportation units. It has a unique mission in that it provides all organic logistical support to its combat battalion except maintenance and medical. Therefore, in developing the model the author has relied upon a combination of Army doctrine and analytical tools, as well as personal experience and military judgment.

A. BACKGROUND

In its quest to develop weapons and tactics and study the phenomena of the battlefield, the Army has amassed a

library of models which have been invaluable in the deployment of the most technically oriented armed force in history. Since World War II, the analytical techniques of researchers have been used by the military community in an attempt to properly answer inquiries concerning the rapidly developing concepts of modern warfare. One would hope that the "acid" test for the decisions which have been made will never be required and this, in itself, is the ultimate goal of ongoing research efforts.

Researchers must be constantly aware of the many aspects of model development. Ideally, model types need to be adapted to a particular problem in the search for possible decision alternatives. The positive and negative aspects of each research method are carefully weighed and all assumptions are stated in a forthright manner. Results are presented in an unbiased format to the decision maker. These key points highlight, yet oversimplify, an extremely complex process. These comments will serve as a foundation for the following paragraphs as the discussion moves from the process of modelling pure combat into the area of logistics modelling.

The underlying point to be made concerns the scope of any model. In the process of model development, especially combat modelling, a fact which must be accepted is that no model is perfect and certain limitations will exist. Combat is a complex interaction of many tangible and intangible variables. Since a model is an abstraction of reality, the

developer will make certain assumptions concerning the combat process. Generally, limitations on computer time and capacity will control the amount of enrichment that may be achieved. As abstraction increases, however, more assumptions are generally introduced and this usually leads to a decrease in realism within the model.

This thesis is concerned with a specific aspect of logistics in a theater of operations. Logistics is a major area in the combat process encompassing many critical functions which contribute to the results of any conflict. Several Army models of significant importance do not consider logistics for various reasons. Generally speaking, only models which simulate large unit combat are capable of considering the logistics function.

The simultaneous modelling of logistics and combat is an extremely difficult task considering the multitude of diverse functions to be performed. For instance, supply is concerned with a virtually endless stream of commodities which support combat units as well as the support units themselves. Obviously, certain aggregation of these products must be achieved in a model. Possible categories might include petroleum, oil, and lubricants (POL), ammunition, repair parts etc. As a matter of fact, the Army has ten classes of supply which are readily adaptable to the modelling requirement of aggregation. Other logistics functions include maintenance, transportation and medical services. Here

again, the functions are conveniently organized in Army units within the Division Support Command (DISCOM) and the Corps Support Command (COSCOM). Ideally, a good representation of logistics would include those factors and demonstrate their impact upon the readiness of units for combat. Often that impact is measured in terms of days of supply for a given unit. For example, a unit assigned a supply status of five days might be considered 100% combat effective for that duration. Below a certain level, say two days, a unit would be degraded in some manner so as to reflect a less than combat ready posture. Up to this point, the comments have been general and no differentiation has been made with respect to stochastic simulation versus deterministic models. In either case, the preceding points apply on a macro level.

A point has now been reached whereby specifics are appropriate. The underlying point of this work is concerned with logistics at a micro level. Logistical functions have primarily been modelled on a large scale basis, as noted earlier. The Army has relied on unit capability when planning for operations. These same measures are also applied to models used for analysis. Unit capability takes into account the many variables present in the daily operational environment in order to measure the mean output expected in the long term. This thesis suggests that an ongoing review of unit capability is a worthwhile idea to assure viable planning factors. One method of verification is to use a computer

simulation model of a given type unit in a Theater of Operations. This process of verification is readily applied to logistics units since the MOE's of such units are well defined, understood, and conveniently measurable. This is not the case with combat units. The basic difference lies in the nature of the mission. For a combat unit to be modelled, some information must be available regarding an opposing force, and assumptions must fill in the void of the unexpected or the unknown. In a logistical unit, the equipment and personnel dominate mission accomplishment. Any consideration of enemy action against a logistical unit can be included as a variable much the same way as maintenance affects mission performance. The enemy factor is no less important in a logistical model but it can be treated in a parametric sense as a variable since the mission of the logistics unit is performance in terms of factors for which information is well known.

It is appropriate at this point to consider some points on the framework within which this study was conducted. The computer simulation is but one mode to view the system. It offers several advantages to include simplicity, speed, and flexibility. This thesis is an attempt to highlight the importance of small unit logistics and bring attention to the impact of combat losses on a logistics unit. One popular method of logistics modelling is a computer simulation designed in gross terms through the employment of network

techniques. This method treats commodities as flow similar to a pipeline whereby the system is controlled through the manipulation of sources and sinks. It is to be remembered that each link in a network represents a unit of military personnel and equipment susceptible to the hazards of the combat zone. However, the Monte Carlo simulation permits a relatively close look at the individual elements in the unit. In short, unit capability should not be treated as a fixed, well-known constant, but rather a variable, since it is composed of many other variables existing in the environment. For many reasons most combat models do not and cannot fully incorporate the impact of the logistics factor. Often, it is treated quite superficially. This thesis offers an alternative which could be inserted as a subroutine in larger models to control the maximum combat potential of a combat unit by simulating the movement of each supply load. The program is relatively compact and parameters can be varied to coincide with scenario specifications.

The previous discussion has outlined a motivation for the model to be developed in this thesis. Small unit logistics is a relatively simple operation to model since logistics units are by their nature specialized. Variables which impact on the system can be varied parametrically and the output is a valuable source of input to combat models or other logistics models. Degradation of unit capability through the application of probabilistic combat factors will essentially "worst case" the accomplishment of unit mission.

B. SUPPORT OF A TANK BATTALION

The introduction of tank warfare during World War I dramatically changed the methods of war in terms of mobility and firepower. Those with the foresight to recognize its potential were quick to admit that a change in combat doctrine can only be successful with a corresponding change in logistics doctrine. Added mobility meant unprecedented fuel requirements and mechanical repair capability. Greater firepower demanded ammunition in seemingly astronomical quantities. American military stagnation between the wars was highlighted by the refusal to accept this progressive form of cavalry to replace the horse. On the other hand, German "blitzkrieg" tactics included planning for the necessary logistic support of mobile cavalry with the result that only the weather stemmed the tide of the Nazi armored onslaught in Russia in 1941. The United States finally developed the art of tank warfare but Patton's offensive of 1944 was delayed for lack of supply. Even the all out logistical effort of the famed Red Ball Express could not sustain the momentum. In recent years, the logistical system has modernized and has demonstrated a unique capability to perform a multitude of intricate support tasks. With these thoughts in mind, the discussion turns to the challenges of the future.

Within every mechanized division, the U. S. Army has assigned several Tank Battalions each equipped with 54 M-60 series tanks. Each tank carries approximately 63 rounds of 105mm ammunition of several types which is referred to as the

stowed load. Additionally, the basic load includes .50 caliber and 7.62mm machine gun ammunition. Other weapons in the battalion include Redeye missiles, 4.2 inch mortars, 20mm cannons, and small arms.

The Tank Battalion is 100% mobile. The large weapon systems noted above are mounted primarily on tracked vehicles. Most of the vehicles, tracked as well as wheeled, operate on diesel fuel. A tank battalion operating in a tactical environment consumes large quantities of fuel, oil, and lubricants entailing major support requirements.

The organic logistical element of a tank battalion is the Support Platoon. This unit is the vital link between the combat unit and a worldwide logistical support system developed by the Department of Defense. The S-4 Staff Supply Officer monitors the activities of the Support Platoon and is responsible for the preparation and execution of the Logistics Plan of the unit. In a combat environment the platoon operates from the battalion Field Trains located directly behind the combat elements. From this position, the platoon shuttles supplies from Division and Corp level supply points to the combat units.

In order to support the fuel requirements of the battalion, at least five of the platoon's vehicles have fuel pods mounted on them. These trucks are then dispatched on a temporary basis to the company and battalion Combat Trains areas for fuel support. Of course, the pods are placed on

another truck in the event of a breakdown, if the time to repair the vehicle would be excessive.

Ammunition is issued by Corps from an Ammunition Supply Point (ASP) located in the Division Rear area. The receiving unit is responsible for loading the ammunition, and in practice an extra truck is utilized for troop transport to and from the ASP on a daily basis. Ammunition for the 105mm main gun on a tank is packaged two rounds per box which weighs approximately 150 pounds. Ideally, four men are used to load a truck. If ammunition is loaded properly, a good team can load approximately 100 boxes in less than one hour. However, this pace is difficult to maintain.

Vehicles are committed to a multitude of other tasks in their support role. Delivery of general supplies requisitioned through the Division Supply Office, movement of equipment and reserve supplies, adminstrative troop transport, and support of the field mess operations are but a few. All requests for transportation are approved by the battalion Operations Section and coordinated with the S-4 Officer. Any drastic change in the support platoon's capability may require additional assistance from the Division Motor Transport Company. That unit is equipped with the larger tractor-trailer combination vehicles, but the unit mission prohibits movement of ammunition. Herein lies the importance of the Support Platoon in its direct support role.

A final, important aspect of the operation of the platoon concerns convoy operations. The purpose of a convoy is to

provide control and security for the movement of cargo. As with any military operation, convoys must be well planned and executed to insure mission accomplishment. Convoy discipline requires that drivers are aware of operating procedures and instructed in actions to be taken in the event of emergency. Drivers must be experienced since no radios are installed in trucks. Speed and spacing appropriate for the terrain, weather, and tactical situation are critical elements in an orderly movement. In the event of ambush, drivers must respond quickly. If caught in a kill zone, vehicles must exit the area as quickly as possible. In short, convoy operations involve more than just driving.

II. DESCRIPTION OF THE MODEL

A. OVERVIEW

The model simulates the operation of the Support Platoon described in the previous section. Performance of the unit is determined by the total number of vehicles which successfully deliver ammunition during a predetermined period of time. The unit commences operation with a certain number of vehicles to perform its mission. Each vehicle is evaluated with regard to its availability for a given day. If a vehicle is operational, it performs a round trip from the combat unit to the Ammunition Supply Point. A maximum of three trips may be made each day. Upon completion of a trip, another maintenance evaluation may be made. During a trip, all vehicles in a convoy may be subjected to an ambush. Each vehicle is then evaluated regarding its survivability. For each vehicle lost due to combat, a replacement is added to the unit after a certain delay. This short outline will be expanded in the following sections.

B. ASSUMPTIONS

Logistics operations are continuous and repetitive. Support systems are designed to process routine actions. Unusual requirements normally burden a system, yet cause it to demonstrate its flexibility. For modelling purposes, the initial assumptions limit the scope of the model to the critical functions of the system. In other words, the

simulation of fundamental activities of the mission should be the basic design of the model. Special requirements may be designed into a model as subroutines, but it may be difficult in many systems to determine exactly what these are. Such is the case with this model.

The model assumes that the Support Platoon supports a "pure" tank battalion. In actual operations, the supported unit would probably be a task force, consisting of two tank companies and one infantry company rather than three tank companies. This cross attachment reflects the combined arms concept for operations in a conventional war, which calls for a tank battalion to trade one company with an infantry battalion. However, the support platoon of the infantry battalion would provide the same support to the attached tank company. The model merely aggregates that support in terms of the tank battalion. The output capability of the Support Platoon measured in truckloads remains the same regardless of the units it supports.

The model assumes that drivers are always available. Administrative and combat losses are not included as a limiting factor. In one sense, this assumption is reasonable, since other personnel in the battalion could function as drivers if required. However, the pool of experienced drivers would be limited.

In the determination of the parameter which establishes the initial number of trucks available for the ammunition transport mission, several assumptions have been made. All

vehicles that are not utilized for fuel or ammunition are combined into one category. This category includes non-operational fuel trucks and trucks assigned to other missions. Throughout any single execution of the model, this value remains constant. This is reasonable since most drivers and their respective vehicles may often be dedicated to a particular mission. Increased efficiency results when a driver becomes familiar with hauling over the same route. The assumption is that the number and type of mission tasks remain consistent from day to day. Therefore, the maximum number of trucks assigned to the ammunition mission remains fixed. Degradation of unit capability is assessed only for ammunition carrying vehicles. Reduction of non-ammunition vehicles is fixed in the constant mentioned above. In this regard, it would appear that the model places priority truck assignment on missions other than that of ammunition. This is not quite true, since a subjective value based on experience is given to the constants mentioned above. Also, the model is capable of ranging over all possible values in order to indicate an expected value.

Several assumptions have been required concerning the ambush. All vehicles are assumed to be susceptible to enemy fire. The long range of weapons and the possible variations regarding terrain have necessitated that those effects be factored into the probability of kill parameter. Also, the length of convoys does not impact on this parameter. Longer convoys would realistically isolate certain vehicles from

the kill zone. However, the kill zone size is actually a function of the size of the enemy force. Other complexities in the parameter determination result from the fact that vehicle speeds increase immediately after the initial firings, so one would expect the probability of kill to decrease with time. The model only considers one degree of "kill". Partial damage and cargo salvage are not modelled. This assumption is based on the high degree of vulnerability of an unarmed, wheeled vehicle. The occurrence of an ambush does not curtail operations for the day if other trips are planned. In reality, certain delays for reorganization and recovery may occur.

C. MEASURE OF EFFECTIVENESS

A Measure of Effectiveness (MOE) is a performance criteria upon which analysis is performed. It is a measured output, which reflects the ability of a system to function in a given environment. The MOE must measure system effectiveness in order for the analyst to quantify and evaluate current and/or potential capability.

Several MOE's may represent the operational capability of a system. Some may be preferable on an economic basis when data collection is involved. Certainly, an MOE may be a mathematical combination of two or more other MOE's. The researcher or analyst must be wary, however, to prevent the introduction of bias through poor selection of an MOE. During the process of model development, it is important to

perform a study of the possible MOE's and systematically determine the most appropriate through a decision making process.

In an operational environment, Army motor transport units are rated by daily tonnage capability. Usually this capacity is given for both short haul and long haul movements. The distinction is a function of the number of round trips per day, a short haul usually indicating more than one round trip per day. When reporting on the results of an operation, data is often presented in units of ton-miles (ton-kilometers). This MOE combination may be misleading if for no other reason than its usually high value. The preferred MOE should be one which indicates the cargo classes which have been transported.

Since the primary area of interest of this study concerns only ammunition transport, the MOE selected is simply truck loads moved during a period of time. The time periods selected are points of analysis at three, five, fifteen and thirty days. These time periods are considered sufficient and appropriate to estimate transport capability for the crucial initial period of a European style conflict.

No attempt is made in this thesis to estimate quantities of ammunition in terms of total rounds by type. The model functions independently of both the supply in the logistics system and the demand created by the combat unit. Since this thesis is concerned with capability, the selected MOE offers estimates which are easily understood. For any given

scenario, planners might determine whether sufficient capability exists to meet a demand for ammunition. Fluctuations in combat intensity will vary this demand and thereby indicate the need to augment (or decrease) the capability for the long term.

D. DESIGN OF THE EXPERIMENT

This section presents the model as a mathematical function to be analyzed by classical statistical methods. Procedures of this type, including the Analysis of Variance (ANOVA), require several assumptions which are briefly stated.

This thesis proposes that the Measure of Effectiveness (MOE), total truckloads delivered, is determined by the additive effects of the following main factors:

1. maximum number of trucks available
2. maintenance down time
3. loss of vehicles due to ambush
4. ability of the enemy to interdict the supply route
5. enemy proficiency in the destruction of convoy targets
6. time to replace lost vehicles

In order to investigate the model and determine the simultaneous effect of all factors, a completely crossed or full factorial design was peformed. Notationally, the model appears as Appendix A.

The factorial design has certain inherent advantages as follows:

1. residual degrees of freedom increase rapidly with the addition of each level of a factor, thereby increasing the efficiency and sensitivity of the design.
2. the design provides the opportunity to observe the impact of any interaction effects.
3. where no prior knowledge about the underlying population exists, the factorial offers a flexible means of testing hypothesis and estimating parameters.

In order to limit the complexity of the model and be compatible with analysis programs, the following four factors are selected for simulation runs of the model:

VARIABLE NAME	FACTOR	GENERIC NAME	NO. OF LEVELS	VALUES
REPL	A	Replacement Time	2	3,8 Days
BUSH	B	Probability of Ambush	2	0.1, 0.2
TRIP	C	No. of Round Trips	3	1,2,3, Trips per day
INUM	D	Maximum No. of Vehicles	3	15,12,9 Vehicles

In classical analysis the "best" estimates of the parameters are determined by the Method of Least Squares. The adjective "best" implies that the factor estimates have the following desireable properties:

1. unbiased
2. consistent
3. efficient
4. minimum mean square error

The cost to insure these properties may be measured by the significance of the assumptions that accompany the theoretical underpinnings in the Gauss Markov Theorem. Specifically, these assumptions are:

1. $E[e_i] = 0$
2. $E[e_i^2] = \sigma^2$
3. $E[e_i, e_j] = 0 , \quad i \neq j$.

The interpretation of the symbology is that the experimental errors are distributed with mean zero and common variance over all observations. Furthermore, the errors are uncorrelated. Independence is maintained by controlling the numerical seed values read into the computer. The string of random numbers drawn by the computer for Monte Carlo purposes is segmented so that each replication uses a separate portion of the same string. This breakdown assures that repetition of a sequence of numbers is avoided.

III. RESULTS

The accuracy of the model is governed by the number of replications of the experiment. For purposes of this work, five iterations of thirty-six parameter sets have been run. Analysis is undertaken at four points in time. A more detailed study would include hundreds of replications and daily points of analysis in the hope of achieving steady state stability with low error variance.

The following sections describe the results by first presenting all values of the MOE, truckloads delivered, at Appendix B. For each analysis point there are 108 values listed with the numerical levels of each of four factors. Recall that two of the original six factors are held constant at one level. They are the probability of kill against a given vehicle and the probability of nonoperational status for a vehicle. Essentially, the impact of these factors, E and F, has been combined into μ, the overall mean.

The reduced model for analysis is notationally similar to the full six factor model and is also presented as Appendix A.

A. ANALYSIS OF VARIANCE

The Statistical Package for the Social Sciences (SPSS) was utilized for computation of the classical Analysis of Variance. All results from the ANOVA's are located at Appendix C. SPSS runs are presented for each of the four analysis points.

At the three day point, the effect of the replacement time (REPL) is not statistically significant. This is to be expected since no vehicles could arrive as replacements until at least three full days have elapsed after the loss occurred. The effects of the other three factors are highly significant. The two way interactions are significant as a group but are primarily influenced by a single two way interaction. The two way interaction between ambush probability and the number of trips (BUSH x TRIP) is apparently responsible as the driving factor. The null hypothesis pertaining to the main factor REPL (A) is:

H_o: $A = 0$, and alternatively

H_1: $A \neq 0$.

The null hypothesis cannot be rejected and the conclusion is that the replacement time does not have an effect on the MOE. The test for the interaction of TRIP and BUSH (BC) is:

H_o: $(BC) = 0$, and

H_1: $(BC) \neq 0$.

The interpretation is that the combined effect of the number of trips and the probability of ambush are jointly non-zero. It is concluded that the model is sensitive to a change in

a given combination of the levels of these factors. The underlying reason could probably be attributed to the expected 50% reduction of vehicles when ambushed. That impact on the highly significant number of trips may account for their joint significance. The three way interactions are significant as a group primarily influenced by the combination of TRIP, REPL and BUSH but the interpretation is unclear so no attempt will be made.

The Multiple Classification Analysis (MCA) confirms the above results by depicting the numerical value of the mean and the main factor effects. Not surprisingly, the effect of replacement time has low value of only 0.14 truckloads. The multiple R-squared, a measure of the variation in the MOE explained by the model, has a value of 0.608. This is considered good performance considering the randomness and multitude of Monte Carlo draws as well as the small sample size. The multiple-R, a measure of the correlation between the predicted MOE and the true MOE, is a respectable 0.779.

Since the main factors INUM and TRIP each have three levels, the rejection of the null hypothesis, H_o: $C = 0$ and H_o: $D = 0$, does not indicate which levels of each factor are significantly different in their effects. Therefore, a one way Analysis of Variance (ANOVA) is used to test the hypotheses:

H_o: C_k are all equal $\quad k = 1, 2, 3$

H_1: C_k are not all equal,

and

H_o: D_ℓ are all equal $\quad \ell = 1, 2, 3$

H_1: D_ℓ are not all equal.

The ANOVA leads to rejection in both cases and indicates that the effects are linear when the MOE is plotted against the levels of each factor. The visual impact of this linearity will be evident in a later section of the thesis. The conservative Scheffe's Test for "a posteriori" contrasts compares all pairwise differences of the three means of both INUM and TRIP. The existing differences between level 2 (12 trucks) and level 3 (9 trucks) of INUM are not sufficient to establish that the effects are significantly different. In the case of TRIP, the means of each level differ significantly. The results of the analysis at this point show the tremendous impact of the number of trips on the MOE.

All comments made above in reference to the three day analysis point apply directly to the five day analysis point with minor exceptions. The slight changes in numerical values do not change the conclusions reached. The only change refers to the Scheffe procedure for the difference in the means of the levels of the factor INUM. The difference

between level 1 (15 trucks) and level 2 (12 trucks) is not statistically significant.

At the third analysis point (15 days) the results indicate some changes from the above. All main effects are significant, indicating that sufficient time has elapsed for REPL to become a major contributor to the model. The two way interactions are collectively significant and the major influence comes not only from TRIP and BUSH as before, but also from TRIP and REPL. Three way interactions are no longer significant. The multiple R-squared has increased substantially to 0.722. The linearity continues to be strong among the levels of INUM and TRIP and there is no longer any homogeneity among their means.

All main factors and most two way interactions are highly significant at the thirty day point. The multiple R-squared has increased slightly to its maximum of 0.762. Approximately, 25% of the variation remains unexplained by the model. It is expected that continued replication would reduce this figure a great deal. Non-homogeneity of the means of INUM and TRIP as well as linearity continue to be prevalent.

Although variance estimates have been high throughout the analysis, the 95% confidence intervals for the means of this random effects model have been surprisingly compact. This may be the result of a good R-squared value. The strongest effect throughout the analysis appears to be that of the number of trips. The implication is that the location

of ammunition supply points is a critical decision in the organization of the combat support scheme.

The following summary of the Analysis of Variance indicates those effects which are statistically significant at the 0.05 level.

	ANALYSIS POINT (DAYS)			
SOURCE OF VARIATION	3	5	15	30
MAIN EFFECTS	X	X	X	X
TRIP	X	X	X	X
INUM	X	X	X	X
REPL			X	X
BUSH	X	X	X	X
2-WAY INTERACTIONS	X	X	X	X
TRIP x INUM				X
TRIP x REPL			X	X
TRIP x BUSH	X	X	X	X
INUM x REPL				X
INUM x BUSH				
REPL x BUSH				
3-WAY INTERACTIONS	X	X		
TRIP x INUMx REPL				
TRIP x INUM x BUSH				
TRIP x REPL x BUSH	X	X		
INUM x REPL x BUSH				
4-WAY INTERACTIONS	*	X		

* indicates significance at the 0.051 level

X indicates significance at the 0.050 level

The reader's attention is directed to the pattern of the components which are significant. It should be noted that the factor TRIP is present in all but one significant interaction.

B. MEAN VALUE DIFFERENTIAL ANALYSIS

This section is based on a very illuminating method of analysis used to survey the output data. The Mean Value Differential Analysis (MVDA) program is capable of determining the mean values of data arranged in any combinatorial order of factor levels. The output enables the user to view the effects of two or more factors simultaneously and this is invaluable in the preparation of graphic results. Some sample output from the MVDA is located in Appendix C. Appendix D contains all graphs produced from results of the MVDA program.

The following tables synthesize the relative performance of the MOE by ranking each parametric case for a given figure. The mode of the ranks is then assigned to each case. The significance of the asterisk will be made clear in the discussion.

TABLE 1. Ranking of Parametric Cases of Figures 1 - 6 (MOE at 30 Days)

CASE	NO. OF TRIPS	REPLACEMENT TIME (DAYS)	FIGURE 1	2	3	4	5	6	MODE OF RANKS
A	1	3	5	5	5	5	5	5	5
B	2	3	2*	4	3	2	2	2	2
C	3	3	1*	1*	1	1*	1	1	1
D	1	8	6	6	6	6	6	6	6
E	2	8	4	3	4	4	4	4	4
F	3	8	3*	2*	2	3	3	3	3

NOTE: Lower ranks are associated with higher MOE values.

TABLE 2. Ranking of Parametric Cases of Figures 7 - 12 (MOE at 30 Days)

CASE	MAX. VEHICLES AVAILABLE	REPLACEMENT TIME (DAYS)	FIGURE 7	8	9	10	11	12	MODE OF RANKS
A	15	3	1	1*	1*	1	1	1*	1
B	15	8	2	2	3*	2	3	3	2,3
C	12	3	3	4	2*	3	2	2	2
D	12	8	4	3	4*	5	5	5	5
E	9	3	5	5	5	4	4	4	4,5
F	9	8	6	6	6	6	6	6	6

TABLE 3. Ranking of Parametric Cases of Figures 13 - 16 (MOE at 30 Days)

CASE	NO. OF TRIPS	MAX. VEHICLES AVAILABLE	FIGURE 13	14	15	16	MODE OF RANKS
A	1	15	7	7	7	5	7
B	1	12	8	8	8	8	8
C	1	9	9	9	9	9	9
D	2	15	3*	2	3	2	2,3
E	2	12	5	4	4	3	4
F	2	9	6	6	6	7	6
G	3	15	1*	1*	1*	1	1
H	3	12	2*	3	2*	4	2
I	3	9	4	5	5	6	5

TABLE 4. Ranking of Parametric Cases of Figures 17 - 22 (MOE at 30 Days)

CASE	MAX. VEHICLES AVAILABLE	P(AMBUSH)	FIGURE 17	18	19	20	21	22	MODE OF RANKS
A	15	0.1	1	1*	1*	1	1	1*	1
B	15	0.2	2	2	2*	2	3	3	2
C	12	0.1	3	3	3*	3	2	2*	3
D	12	0.2	4	4	5	4	5	5	4,5
E	9	0.1	5	5	4	5	4	4	4,5
F	9	0.2	6	6	6	6	6	6	6

TABLE 5. Ranking of Parametric Cases of Figures 23 - 28 (MOE at 30 Days)

CASE	P(AMBUSH)	NO. OF TRIPS	FIGURE 23	24	25	26	27	28	MODE OF RANKS
A	0.1	1	5	5	5	5	5	5	5
B	0.1	2	3*	3	2	2	2	2	2
C	0.1	3	1*	1*	1	1*	1*	1	1
D	0.2	1	6	6	6	6	6	6	6
E	0.2	2	4	4	4	4	3	4	4
F	0.2	3	2*	2	3	3	4	3	3

Generally speaking the results offer no surprises. The more favorable parameter combinations produce better values of the MOE. Throughout the analysis, the message is clear that one trip per day produces poor ammunition resupply. It is appropriate to establish a standard to differentiate those parametric combinations which produce a certain desired level of performance. A realistic value is the daily delivery of one stowed load per tank. As a reference point, consider that 510 total truckloads are required in a thirty-day period to insure an average daily resupply of one stowed load per tank. Those cases which produce this amount are so indicated in the tables by an asterisk. Of the thirty-six parametric combinations only six produce the one basic load per day average. They are:

DAILY NO. OF TRIPS	REPLACEMENT TIME (DAYS)	P(AMBUSH)	MAX. VEHICLES AVAILABLE
3	3	0.1	15
3	3	0.1	12
3	3	0.2	15
2	3	0.1	15
3	8	0.1	15
3	8	0.1	12*

The operational conditions required to meet the benchmark are clearly those which are somewhat ideal. Only one of the above combinations contains a pair of less than ideal

parameter values and is so indicated by an asterisk. In four of the above cases, a single parameter value which is less than ideal requires the other three in that combination to be favorable. The obvious conclusion is that continuous resupply requires a minimum of enemy harassment. Almost all vehicles in the unit must be dedicated to ammunition resupply and they must make as many daily trips as possible. Lastly, the unit must receive replacements within a short time of their loss. The impact of any negative influence on the mission must be minimized or prevented.

IV. UTILIZATION OF THE MODEL

A. CONCEPT

The analysis of output data generated by the model may provide certain insights to a "real world" situation. However, the data is so voluminous that one may lose sight of what the "bottom line" actually is. In order to overcome this possibility, it is useful to propose a scenario within which the model may generate typical values applicable to a realistic situation. In this manner, the reader will associate plausible numerical parameters and output with an operational system governed by current Army Doctrine. This approach should clarify several concepts for those uninitiated to Army combat logistics. The following scenario is generally regarded as plausible in open literature, although fictitious units and dates are assumed.

B. SCENARIO

During the mid-1980's, international tensions mounted to an unprecedented level due to many political and economic factors. The stress point was central Europe where negotiations for a reunified Germany had finally broken down. The Warsaw Pact nations, pressed by East German demands for military action, launched a surprise attack to force reunification. NATO forces reeled under the thrust at their center but were able to hold key terrain due to the fact that the Soviet forces altered their doctrine of mass in order to

achieve complete surprise. The impact of superior NATO air power forced a somewhat stable front line inside West Germany. Tactical nuclear weapons were not employed, although their potential use dictated dispersion of units. This dispersion created gaps permitting small unit probes along the line. Logistical units were fully committed in the execution of their vital missions as well as coping with enemy harassment by air, artillery, and infiltration.

The 6th Armored Division (US), located at a strategically important point in the line, was taking advantage of the lull in order to rearm. Typical of its many units, the 1st Battalion, 39th Armor, was being subjected to enemy harassment of its supply line. Combat units were stretched thin and logistical efforts were hampered in their resupply efforts. The Support Platoon of the battalion was primarily concerned with moving 105-mm tank ammunition from the Ammunition Supply Point (ASP) located in the Division Rear Area, a distance of approximately 50km. In order to build up ammunition levels, vehicles of the unit were expected to make three round trips on a daily basis for the next ten days.

The unit was equipped with tactical trucks rated at a five ton capacity. Twenty of these vehicles are authorized in the platoon. Five trucks were generally allocated to the fuel support mission on a permanent basis. Other supply and administrative requirements often further reduced the vehicles available for the transport of ammunition. The support mission was also degraded by maintenance down-time associated with

continuous and intense operational requirements. Finally, enemy infiltration of squads equipped with anti-tank weapons had given rise to the threat of interdiction along the main supply route. The direct result of this threat was loss of capability due to the time required for replacement of vehicles which were destroyed by enemy ambush.

For the next 30 days, planners anticipated a dynamic tactical situation which would alter the impact of the above mentioned factors. The battalion commander desired data on the amount of ammunition he could expect based on current and projected conditions.

C. DISCUSSION OF INPUT PARAMETERS

Based on a projected 30-day period of conflict, the following parameters are variable as input to the model:

1. Probability of ambush occurrence
2. Probability of vehicle non-operation
3. Number of trips per day
4. Initial number of vehicles available for ammunition resupply mission
5. Probability of vehicle destruction by the ambush force
6. Replacement rate for destroyed vehicles.

The first three parameters are variable on a daily basis in order to reflect changing conditions in the tactical situation. The following discussion will attempt to fit reasonable parameter values to the scenario based on subjective grounds and experience.

The occurrence of an ambush is probably the most difficult estimate to make. As mentioned earlier, some information regarding the enemy force must be available. Much of this is obtained as a judgment of the enemy capability, his expected mission and objective, and other lesser known factors concerning his style and degree of aggressiveness. Certain assumptions along these lines are necessary in order to evaluate enemy intentions. For the scenario, three levels of ambush probability will be utilized, each for a ten-day period. Considering that the initial period is stable, a somewhat high value of 0.35 will be utilized. As the enemy prepares for intensified combat action in resuming the offensive, forces will be more concerned with direct confrontation than infiltration. Therefore, values of 0.25 and 0.10 will be applied to the second and third ten-day periods respectively. It should be noted that the declining character of this parameter is due to the manner in which the scenario was constructed. If the scenario had been developed around the initial attack and breakthrough, then one could present arguments for an increasing ambush probability.

In order to introduce the maintenance factor into the scenario, a judgment must be made on the parameter relative to a combat situation. Army references generally dictate that commanders plan for a 75% availability rate. This figure indicates that of all vehicles authorized, the commander may expect to have three-fourths available to be utilized as task vehicles for mission performance. The degradation is due to

all causes in this case. Vehicles that would have been considered non-operational due to maintenance in a peacetime environment will often be utilized in a combat situation. Generally, only the most serious maintenance deficiencies will cause non-availability of any particular vehicle. For example, any vehicle fuel leak in a peacetime environment would be grounds for deadline status. In a combat situation, minor fuel leaks would probably not deter use of the vehicle. With these thoughts in mind regarding the scenario, the initial ten-day period will be assigned a probability of non-operation of 0.15 since the situation is stable and maintenance would be emphasized in preparation for an impending period of active combat. The second and third ten-day periods will be assigned values of 0.20 and 0.25, respectively. In order to account for the breakdown of vehicles which have been dispatched, a 0.05 value for additional maintenance degradation will be applied after each round trip.

The number of round trips per day is a function of several factors in the tactical environment. The travel time is directly related to the distance and vehicle speed. Furthermore, speed is a function of terrain, weather, road conditions, cargo type and weight, and the traffic density including the length of the convoy. The terrain in central Europe is generally hilly. Many four-lane "autobahn" roadways exist with limited access. However, wartime conditions would generate a tremendous volume of civilian traffic on these highways and the resulting congestion would inhibit full

military utilization. There exists a dense network of narrow two-lane, hard-surface secondary roads which are generally not banked and are poorly marked. Travel is generally slow on these roads due to the high density of small towns with narrow cobblestone streets. The advantage of these secondary roads is that they would be difficult to interdict and they offer many alternate routes between two points. Major highways are generally well cleared and offer little off-road concealment. The weather is quite variable with seasonal changes, so very little can be anticipated for short term scenarios. The number of trips per day based on military experience may be determined as follows:

ONE WAY DISTANCE	TRIPS PER DAY
160km - 90km	1
50km - 90km	2
less than 50km	3

Admittedly, these values are very sensitive to the changes in the situation and environment. Nevertheless, they are reasonable and will serve to demonstrate the potential of the model as well as the extremes in a scenario.

Several other factors have been integrated into the table. Although a ten-hour day may be planned for the mission, time must be included for maintenance of vehicles. Also, drivers and loading crews require meals and rest periods. A major

time factor is that of loading and unloading of cargo. Here again, time is subject to a good deal of variability. It would not be unreasonable to assume that vehicles must queue for access to the Ammunition Supply Point since many units are supported by one source. Documentation preparation and processing cause further delays as well. For the scenario, three trips per day will be planned for the first ten-day period. After the initial attack, combat units have been compressed against support units. For the second ten-day period, a factor of two trips per day will be used, since NATO forces will either advance or support units will relocate further from the battle area. Similar reasoning will justify the one trip per day for the final period.

The initial number of vehicles dedicated to the ammunition mission is an important consideration and must reflect some judgment about other tasks which "compete" for transportation assets. The maximum of fifteen trucks is reduced by the sum of the following:

1. trucks to replace non-operational fuel trucks
2. trucks assigned to non-ammunition supply, administrative transport of troops, and ration delivery
3. trucks to replace those in 2 which are nonoperational for maintenance.

The remainder of the trucks are considered available for use in the transport of ammunition. These vehicles are reduced separately by the maintenance factor due to the more severe operating conditions inherent in the mission. When considering

trucks included in the three categories above, it is important to realize that the platoon supports five companies as follows:

1. three Tank Companies
2. one Headquarters and Headquarters Company
3. one Combat Support Company.

The figure selected as the initial number of trucks available is treated as a constant in the model. In effect, it is the <u>maximum</u> number available on any given day. In reality, of course, the number is variable but its variance would likely be low. For the scenario, a value of ten trucks is quite realistic.

The replacement time is a representation of the capability of the logistical system in a Theater of Operations to respond to high priority requisitions for major end items. The parameter is measured in days and Army regulations outline shipping objectives depending on the priority of the request. Of course, the priority would depend on the judgment of the commander concerning the ability of his unit to perform its mission without any particular vehicle. Certainly, the number of vehicles currently on hand in the unit would be a consideration although the model will not perform the decision procedure on this basis. Transport assets are essential to the success of any military operation and are a critical element of a highly mobile force. In the case of the scenario, where support of an armored unit involves large quantities of ammunition, the shipping delay for replacements could mean the

difference in the transport of hundreds of rounds. In selecting a replacement factor of six days, it is assumed that many other units have similar demands and this creates a somewhat lengthy delay in the supply system.

The final parameter to be discussed is the probability of kill, given an ambush against a vehicle. The selection of any value for this parameter is open to question. But the point to be made is that it should be included as a factor in logistical planning. Logistical units maintain the very lifeline of combat units and it is reasonable to assume that they are a prime target in the enemy's plan.

Several considerations have led to the selection of 0.6 as a parameter. The enemy is equipped with wire guided anti-tank missiles. Open literature suggests the weapons may be reasonably accurate up to 2500 meters. This range permits the enemy to occupy many excellent positions around and above a kill zone.

The terrain in central Europe is ideal for ambushes. Covered hilltops often parallel roads in clear valleys. The sharp unbanked curves of many secondary roads require vehicles to slow down considerably and loaded five-ton trucks do not accelerate quickly. Therefore, a kill zone which includes several curves offers the enemy ample time to launch the missiles with accuracy. Narrow secondary roads may be easily blocked. Ambush doctrine indicates that lead and tail vehicles are primary targets. Their destruction may force escaping vehicles off the road into ditches and possibly muddy fields.

Another aspect of the ambush concerns the sensitivity of the cargo. Near misses can often be disastrous for unprotected vehicles. Armored escorts would be a rare event since combat vehicles and helicopter resources are required in forward positions. Hardened vehicles, those with steel plate and sandbags, reduce the amount of cargo space available and vehicles with armed troops reduce the cargo capability as well.

Basically, the convoy remains a lucrative and vulnerable target on the modern battlefield as it has throughout history. One can expect that any properly executed ambush will generally favor the attacker.

D. RESULTS

While the scenario and the discussion of its parameters provide insights into the operational aspects of the combat mission of the Support Platoon, the data generated offers additional information for analytical consideration. In fact, the following analysis format is appropriate for all thirty-six parameter combinations of the four factor model in Section III.

The combat losses as a function of the probability of kill and probability of ambush are quite significant. It is obvious that a regression model may be proposed in order to determine the relationship between the MOE and the total losses. Inclusion of the total nonoperational vehicles as an explanatory variable was considered and rejected since multicollinearity exists among the variables. The computer output of the model provides these values on a per day basis.

Using the scenario parameters, twenty replications of the simulation were run. The correlation between the MOE and total losses for thirty days is 0.84.

A plot of the MOE with the independent variable indicates that a linear fit is probably the most appropriate. Prior analysis in this thesis indicates this relationship also. The model is

$$Y = a + bX + e$$

and the parameter estimates are

$$\hat{a} = 303.2737$$
$$\hat{b} = -5.4199 \; .$$

The R-squared for the model is 0.705. A t-test confirms the significance of the parameter estimates at the 0.05 level. The sample mean of Y is 152.6 truckloads with an unbiased sample variance of 629.41. The residual variance of the model is 195.68. As an indicator of the efficiency and fit of the data, this variance reduction is noteworthy.

The interpretation of the model is that if combat losses are reduced to 0 the expected number of truckloads delivered is 303. The 95% confidence interval for this parameter is

$$254.61 \leq \hat{a} \leq 351.93.$$

The slope parameter indicates that a one unit reduction in losses will produce a corresponding 5.41 increase in the number of truckloads. The implication to the commander is

that any measure he may undertake to reduce losses will reap benefits. Five truckloads of 105mm tank ammunition may amount to 1000 rounds. Of course, these preventive measures would reduce the parameter values of the scenario but the slope value removes the estimation problem in deciding what parametric change is equivalent to a particular measure. The 95% confidence interval for the slope parameter is:

$$-5.97 \leq \hat{b} \leq -4.87.$$

This modelling procedure offers the analyst a simple method to be used in forecasting and planning. For this data the 95% confidence interval about the mean is

$$123.21 \leq \hat{Y} \leq 181.99.$$

At first glance this appears to be wide but it essentially means only a 1.96 truck per day differential at the extremes.

Recalling the conditions of the scenario, the maximum possible truckoads during the period is

2 TRIPS PER DAY (AVE) x 30 DAYS x 10 TRUCKS = 600 TRUCKS.

The expected fraction of trucks lost to the enemy on any trip is a function of ambush and kill parameters:

EXPECTED FRACTION LOST = P(AMBUSH) x P(KILL) = (0.15) x (0.6) = 0.09

Nine percent of 600 truckloads is 54 trucks which are each lost for the six day replacement time resulting in a total loss of 324 truckloads. The remaining 276 truckloads is comparable to the parameter intercept value of 303.27. These simple calculations lend credibility to the simulation model as a function of its random numbers.

The analysis of Section III did not include multiple values for the probability of kill parameter in the four factor model. Therefore, a check on the sensitivity of the regression model to this parameter is appropriate. Twenty additional trials of the scenario parameters using a kill probability of 0.5 were run. The following information was calculated for the model:

$$\text{R-squared} = 0.789$$

$$\hat{a} = 316.04$$

$$\hat{b} = -5.33$$

$$\bar{Y} = 179.9$$

$$S_y^2 = 597.67$$

Confidence intervals for the parameters are:

$$274.83 \leq \hat{a} \leq 357.25$$

$$-5.83 \leq \hat{b} \leq -4.83$$

The 95% confidence interval for the MOE about the mean is:

$$152.6 \leq \hat{Y} \leq 207.2$$

The residual variance of this model is 168.83.

The t-test for comparing the two populations verifies that the means of the two data sets are statistically different at the 0.05 level. Concerning the sensitivity of the kill probability, it should be noted that a 16.7% decrease in the parameter resulted in a 17.9% increase in the mean of the MOE. In other words, reducing the parameter by 0.1 corresponds to a 27.3 mean truckload increase.

In summary, simple linear regression using ordinary least squares theory provides a viable method of forecasting based on expected loss levels. Further investigation of data in each of the thirty-six parametric conditions wuld provide a set of models that could be used for contingency planning or for input to other models. An important part of any further study would be to establish the consistency of the critical slope parameter.

V. RECOMMENDATIONS AND CONCLUSIONS

It is felt that the objectives of this study have been achieved, yet closing comments are appropriate in relating the results to the operational environment. This thesis highlights the prominent aspects of a typical support operation and indicates expected results for various parametric conditions.

Actual data collected during a test could validate the model. The cost benefit of such a test would have to be carefully considered in view of time and physical resources required. In any event, the acknowledgement of the six factors in the model and their apparent impact dictates further study. The selection of parameter estimates are admittedly subject to much discussion. Any credence given the model reflects the assumption that scenarios of the type suggested by the parameters are indeed credible.

Simple arithmetic calculations show that the resupply of one stowed load of 105mm tank ammunition is equivalent to 3402 rounds per battalion. The one-time lift capability of the Support Platoon is 3000 rounds. The proximity of these figures is not coincidental. The point is that any outside effect will increase the difference between the two values. The magnitude of that difference is indicated in the model results.

Other support activities within the Army may readily be modelled by methods similar to the one employed here.

Specifically, support of an artillery unit would be a prime prospect for such modelling considering the bulk of the ammunition involved. This topic is a potentially lucrative subject of investigation for a Field Artillery Officer who is well versed in the intricacies of the fire support mission.

This use of the model could be enhanced by empirical validation of the parameter estimates such as the probability of kill during engagements. Possibly a combat simulation could be developed which would utilize this model as a subroutine to provide daily quantities of ammunition available as a parameter. Another potential area of study concerns the ammunition supply point at the other end of the supply line. Specifically, the modelling of an ASP would entail supply and demand parameters for Division and higher levels of organization. Finally, a transportation system of many different units could be designed to simulate a Corps level support system. The subject is rich in possibilities and readily adaptable to Monte Carlo simulation.

In essence, the treatment of supply as a random variable rather than a constant induces the commander to use on-hand resources wisely. Furthermore, the budgeting of future resources will become an important tactical decision. These concepts foster the philosophy that the random effects of the battlefield environment apply to support units as well as combat units.

The high statistical significance of the main factors leads to the conclusion that the military must be capable of

controlling their influence. The tactical commander requires adequate organic transport capability in order to maintain support flexibility. Interdiction of supply lines must be minimized by controlling access to rear areas. Failure to achieve this goal will require additional resources if the supply mission is to be accomplished. Regarding destroyed capability, the Army must maintain a responsive supply system to replace lost equipment. Prepositioned equipment surplus is an expensive option but a certain amount may be a cost effective solution. Finally, as has been emphasized throughout this thesis, the optimal location of supply points is critical. They must be conveniently located to the user and at the same time they require the safety of distance from forward areas. It must be remembered that the displacement of a supply point may temporarily interrupt the supply flow.

APPENDIX A

NOTATIONAL MODELS

The model described in this thesis is represented by a full factorial or fully crossed design. This design assumes the additivity of the components in the model and the presence of all factor interactions. The following equation is the full six factor model:

$$Y_{ijk\ell mno} = \mu + A_i + B_j + C_k + D_\ell + E_m + F_n + \text{(all two way interactions)} + \text{(all three way interactions)} + \text{(all four way interactions)} + \text{(all five way interactions)} + (ABCDEF)_{ijk\ell mn} + e_{ijk\ell mo}$$

where

- Y is the truckloads delivered (MOE),
- μ is the overall mean,
- A is the effect of the replacement time in days,
- B is the effect of the ambush probability,
- C is the effect of the number of trips per day,
- D is the effect of the maximum number of vehicles available per day
- E is the effect of the kill probability,
- F is the effect of probability of a non-operational vehicle,

i, j, k, ℓ, m, n, are the various factor levels and o is the number of replications.

The following equation is the reduced model used in the computer simulation since two factors were represented with one level each.

$$Y_{ijk\ell o} = \mu + A_i + B_j + C_k + D_\ell + \text{(all two way interactions)} + \text{(all three way interactions)} + (ABCD)_{ijk\ell} + e_{ijk\ell o}$$

where the symbols are the same as in the full model.

APPENDIX B

VALUES OF THE MOE

This appendix presents the values of the MOE, truck-loads delivered, for each of four analysis points. The first four columns are the levels of each factor as follows:

COLUMN 1: Probability of Ambush

1= 0.1   2=0.2

COLUMN 2: Replacement Time

1=3 days 2=8 days

COLUMN 3: Maximum Number of Vehicles Available per Trip

1=15 trucks   2=12 trucks   3=9 trucks

COLUMN 4: Number of Trips per Day

1=1 trip   2=2 trips   3=3 trips

Column 5 is the replicate number for the parametric case and the MOE value is the last column.

TABLE B-1. Three Day Values

1	1	1	1	1	38	1	2	1	1	1	42
1	1	1	1	2	22	1	2	1	1	2	38
1	1	1	1	3	27	1	2	1	1	3	38
1	1	1	1	4	33	1	2	1	1	4	35
1	1	1	1	5	41	1	2	1	1	5	38
1	1	1	2	1	63	1	2	1	2	1	61
1	1	1	2	2	58	1	2	1	2	2	46
1	1	1	2	3	78	1	2	1	2	3	45
1	1	1	2	4	80	1	2	1	2	4	75
1	1	1	2	5	68	1	2	1	2	5	49
1	1	1	3	1	114	1	2	1	3	1	85
1	1	1	3	2	71	1	2	1	3	2	90
1	1	1	3	3	75	1	2	1	3	3	73
1	1	1	3	4	117	1	2	1	3	4	77
1	1	1	3	5	97	1	2	1	3	5	84
1	1	2	1	1	32	1	2	2	1	1	27
1	1	2	1	2	30	1	2	2	1	2	31
1	1	2	1	3	24	1	2	2	1	3	30
1	1	2	1	4	29	1	2	2	1	4	26
1	1	2	1	5	31	1	2	2	1	5	31
1	1	2	2	1	64	1	2	2	2	1	46
1	1	2	2	2	54	1	2	2	2	2	31
1	1	2	2	3	55	1	2	2	2	3	64
1	1	2	2	4	65	1	2	2	2	4	46
1	1	2	2	5	12	1	2	2	2	5	63
1	1	2	3	1	30	1	2	2	3	1	92
1	1	2	3	2	59	1	2	2	3	2	93
1	1	2	3	3	41	1	2	2	3	3	86
1	1	2	3	4	82	1	2	2	3	4	87
1	1	2	3	5	44	1	2	2	3	5	89
1	1	3	1	1	14	1	2	3	1	1	19
1	1	3	1	2	23	1	2	3	1	2	26
1	1	3	1	3	10	1	2	3	1	3	14
1	1	3	1	4	21	1	2	3	1	4	25
1	1	3	1	5	22	1	2	3	1	5	4
1	1	3	2	1	48	1	2	3	2	1	35
1	1	3	2	2	30	1	2	3	2	2	42
1	1	3	2	3	45	1	2	3	2	3	52
1	1	3	2	4	38	1	2	3	2	4	51
1	1	3	2	5	28	1	2	3	2	5	43
1	1	3	3	1	69	1	2	3	3	1	44
1	1	3	3	2	66	1	2	3	3	2	43
1	1	3	3	3	65	1	2	3	3	3	66
1	1	3	3	4	57	1	2	3	3	4	71
1	1	3	3	5	46	1	2	3	3	5	67

TABLE B-1 Continued

2	1	1	1	1	13
2	1	1	1	2	33
2	1	1	1	3	38
2	1	1	1	4	35
2	1	1	1	5	36
2	1	1	2	1	35
2	1	1	2	2	42
2	1	1	2	3	73
2	1	1	2	4	39
2	1	1	2	5	51
2	1	1	3	1	72
2	1	1	3	2	110
2	1	1	3	3	38
2	1	1	3	4	65
2	1	1	3	5	74
2	1	2	1	1	23
2	1	2	1	2	10
2	1	2	1	3	29
2	1	2	1	4	33
2	1	2	1	5	20
2	1	2	2	1	11
2	1	2	2	2	49
2	1	2	2	3	51
2	1	2	2	4	20
2	1	2	2	5	63
2	1	2	3	1	68
2	1	2	3	2	82
2	1	2	3	3	54
2	1	2	3	4	68
2	1	2	3	5	49
2	1	3	1	1	23
2	1	3	1	2	24
2	1	3	1	3	25
2	1	3	1	4	13
2	1	3	1	5	25
2	1	3	2	1	22
2	1	3	2	2	27
2	1	3	2	3	24
2	1	3	2	4	16
2	1	3	2	5	45
2	1	3	3	1	55
2	1	3	3	2	20
2	1	3	3	3	61
2	1	3	3	4	52
2	1	3	3	5	61
2	2	1	1	1	37
2	2	1	1	2	28
2	2	1	1	3	24
2	2	1	1	4	26
2	2	1	1	5	25
2	2	1	2	1	57
2	2	1	2	2	43
2	2	1	2	3	80
2	2	1	2	4	63
2	2	1	2	5	65
2	2	1	3	1	69
2	2	1	3	2	47
2	2	1	3	3	28
2	2	1	3	4	53
2	2	1	3	5	70
2	2	2	1	1	31
2	2	2	1	2	29
2	2	2	1	3	30
2	2	2	1	4	14
2	2	2	1	5	25
2	2	2	2	1	63
2	2	2	2	2	64
2	2	2	2	3	41
2	2	2	2	4	37
2	2	2	2	5	47
2	2	2	3	1	46
2	2	2	3	2	65
2	2	2	3	3	29
2	2	2	3	4	61
2	2	2	3	5	20
2	2	3	1	1	14
2	2	3	1	2	16
2	2	3	1	3	25
2	2	3	1	4	13
2	2	3	1	5	18
2	2	3	2	1	34
2	2	3	2	2	51
2	2	3	2	3	47
2	2	3	2	4	43
2	2	3	2	5	36
2	2	3	3	1	55
2	2	3	3	2	16
2	2	3	3	3	28
2	2	3	3	4	19
2	2	3	3	5	58

TABLE B-2. Five Day Values

1	1	1	1	1	61	1	2	1	1	1	69
1	1	1	1	2	44	1	2	1	1	2	[illegible]
1	1	1	1	3	[illegible]	1	2	1	1	3	64
1	1	1	1	4	53	1	2	1	1	4	53
1	1	1	1	5	65	1	2	1	1	5	[illegible]
1	1	1	2	1	92	1	2	1	2	1	101
1	1	1	2	2	[illegible]	1	2	1	2	2	[illegible]
1	1	1	2	3	135	1	2	1	2	3	67
1	1	1	2	4	130	1	2	1	2	4	131
1	1	1	2	5	[illegible]	1	2	1	2	5	79
1	1	1	3	1	131	1	2	1	3	1	[illegible]
1	1	1	3	2	[illegible]	1	2	1	3	2	127
1	1	1	3	3	125	1	2	1	3	3	102
1	1	1	3	4	[illegible]	1	2	1	3	4	113
1	1	1	3	5	107	1	2	1	3	5	[illegible]
1	1	2	1	1	93	1	2	2	1	1	[illegible]
1	1	2	1	2	47	1	2	2	1	2	[illegible]
1	1	2	1	3	37	1	2	2	1	3	[illegible]
1	1	2	1	4	51	1	2	2	1	4	57
1	1	2	1	5	51	1	2	2	1	5	[illegible]
1	1	2	2	1	105	1	2	2	2	1	[illegible]
1	1	2	2	2	[illegible]	1	2	2	2	2	58
1	1	2	2	3	[illegible]	1	2	2	2	3	[illegible]
1	1	2	2	4	104	1	2	2	2	4	62
1	1	2	2	5	25	1	2	2	2	5	103
1	1	2	3	1	65	1	2	2	3	1	143
1	1	2	3	2	[illegible]	1	2	2	3	2	124
1	1	2	3	3	77	1	2	2	3	3	151
1	1	2	3	4	121	1	2	2	3	4	[illegible]
1	1	2	3	5	59	1	2	2	3	5	[illegible]
1	1	3	1	1	[illegible]	1	2	3	1	1	[illegible]
1	1	3	1	2	[illegible]	1	2	3	1	2	[illegible]
1	1	3	1	3	[illegible]	1	2	3	1	3	[illegible]
1	1	3	1	4	[illegible]	1	2	3	1	4	[illegible]
1	1	3	1	5	[illegible]	1	2	3	1	5	[illegible]
1	1	3	2	1	80	1	2	3	2	1	[illegible]
1	1	3	2	2	43	1	2	3	2	2	[illegible]
1	1	3	2	3	79	1	2	3	2	3	[illegible]
1	1	3	2	4	52	1	2	3	2	4	[illegible]
1	1	3	2	5	36	1	2	3	2	5	[illegible]
1	1	3	3	1	114	1	2	3	3	1	[illegible]
1	1	3	3	2	34	1	2	3	3	2	[illegible]
1	1	3	3	3	105	1	2	3	3	3	[illegible]
1	1	3	3	4	85	1	2	3	3	4	[illegible]
1	1	3	3	5	[illegible]	1	2	3	3	5	95

TABLE B-2. Continued

2	1	1	1	1	21
2	1	1	1	2	42
2	1	1	1	3	55
2	1	1	1	4	[illegible]
2	1	1	1	5	50
2	1	1	2	1	55
2	1	1	2	2	61
2	1	1	2	3	112
2	1	1	2	4	52
2	1	1	2	5	45
2	1	1	3	1	[illegible]
2	1	1	3	2	143
2	1	1	3	3	59
2	1	1	3	4	36
2	1	1	3	5	33
2	1	2	1	1	35
2	1	2	1	2	[illegible]
2	1	2	1	3	[illegible]
2	1	2	1	4	53
2	1	2	1	5	[illegible]
2	1	2	2	1	32
2	1	2	2	2	67
2	1	2	2	3	72
2	1	2	2	4	37
2	1	2	2	5	[illegible]
2	1	2	3	1	103
2	1	2	3	2	149
2	1	2	3	3	65
2	1	2	3	4	[illegible]
2	1	2	3	5	53
2	1	3	1	1	34
2	1	3	1	2	37
2	1	3	1	3	41
2	1	3	1	4	17
2	1	3	1	5	42
2	1	3	2	1	47
2	1	3	2	2	[illegible]
2	1	3	2	3	50
2	1	3	2	4	30
2	1	3	2	5	71
2	1	3	3	1	85
2	1	3	3	2	38
2	1	3	3	3	91
2	1	3	3	4	[illegible]
2	1	3	3	5	70
2	2	1	1	1	61
2	2	1	1	2	[illegible]
2	2	1	1	3	[illegible]
2	2	1	1	4	35
2	2	1	1	5	35
2	2	1	2	1	[illegible]
2	2	1	2	2	56
2	2	1	2	3	105
2	2	1	2	4	[illegible]
2	2	1	2	5	103
2	2	1	3	1	105
2	2	1	3	2	[illegible]
2	2	1	3	3	23
2	2	1	3	4	77
2	2	1	3	5	[illegible]
2	2	2	1	1	47
2	2	2	1	2	41
2	2	2	1	3	50
2	2	2	1	4	24
2	2	2	1	5	45
2	2	2	2	1	[illegible]
2	2	2	2	2	[illegible]
2	2	2	2	3	[illegible]
2	2	2	2	4	51
2	2	2	2	5	[illegible]
2	2	2	3	1	60
2	2	2	3	2	75
2	2	2	3	3	40
2	2	2	3	4	59
2	2	2	3	5	[illegible]
2	2	3	1	1	18
2	2	3	1	2	20
2	2	3	1	3	31
2	2	3	1	4	18
2	2	3	1	5	20
2	2	3	2	1	[illegible]
2	2	3	2	2	62
2	2	3	2	3	70
2	2	3	2	4	75
2	2	3	2	5	51
2	2	3	3	1	[illegible]
2	2	3	3	2	26
2	2	3	3	3	[illegible]
2	2	3	3	4	[illegible]
2	2	3	3	5	[illegible]

TABLE B-3. Fifteen Day Values

1	1	1	1	1	154
1	1	1	1	2	170
1	1	1	1	3	150
1	1	1	1	4	179
1	1	1	1	5	172
1	1	1	2	1	324
1	1	1	2	2	[illegible]
1	1	1	2	3	[illegible]
1	1	1	2	4	[illegible]
1	1	1	2	5	[illegible]
1	1	1	3	1	[illegible]
1	1	1	3	2	[illegible]
1	1	1	3	3	[illegible]
1	1	1	3	4	377
1	1	1	3	5	[illegible]
1	1	2	1	1	[illegible]
1	1	2	1	2	[illegible]
1	1	2	1	3	[illegible]
1	1	2	1	4	157
1	1	2	1	5	112
1	1	2	2	1	260
1	1	2	2	2	190
1	1	2	2	3	231
1	1	2	2	4	215
1	1	2	2	5	204
1	1	2	3	1	[illegible]
1	1	2	3	2	[illegible]
1	1	2	3	3	[illegible]
1	1	2	3	4	[illegible]
1	1	2	3	5	[illegible]
1	1	3	1	1	75
1	1	3	1	2	115
1	1	3	1	3	[illegible]
1	1	3	1	4	[illegible]
1	1	3	1	5	131
1	1	3	2	1	[illegible]
1	1	3	2	2	[illegible]
1	1	3	2	3	[illegible]
1	1	3	2	4	146
1	1	3	2	5	[illegible]
1	1	3	3	1	250
1	1	3	3	2	222
1	1	3	3	3	[illegible]
1	1	3	3	4	274
1	1	3	3	5	[illegible]
1	2	1	1	1	[illegible]
1	2	1	1	2	[illegible]
1	2	1	1	3	[illegible]
1	2	1	1	4	124
1	2	1	1	5	112
1	2	1	2	1	[illegible]
1	2	1	2	2	[illegible]
1	2	1	2	3	[illegible]
1	2	1	2	4	[illegible]
1	2	1	2	5	187
1	2	1	3	1	[illegible]
1	2	1	3	2	[illegible]
1	2	1	3	3	[illegible]
1	2	1	3	4	[illegible]
1	2	1	3	5	[illegible]
1	2	2	1	1	107
1	2	2	1	2	[illegible]
1	2	2	1	3	[illegible]
1	2	2	1	4	77
1	2	2	1	5	[illegible]
1	2	2	2	1	[illegible]
1	2	2	2	2	[illegible]
1	2	2	2	3	193
1	2	2	2	4	[illegible]
1	2	2	2	5	225
1	2	2	3	1	[illegible]
1	2	2	3	2	[illegible]
1	2	2	3	3	[illegible]
1	2	2	3	4	[illegible]
1	2	2	3	5	[illegible]
1	2	3	1	1	[illegible]
1	2	3	1	2	[illegible]
1	2	3	1	3	[illegible]
1	2	3	1	4	[illegible]
1	2	3	1	5	[illegible]
1	2	3	2	1	137
1	2	3	2	2	[illegible]
1	2	3	2	3	[illegible]
1	2	3	2	4	162
1	2	3	2	5	[illegible]
1	2	3	3	1	[illegible]
1	2	3	3	2	[illegible]
1	2	3	3	3	177
1	2	3	3	4	[illegible]
1	2	3	3	5	[illegible]

TABLE B-3. Continued

2	1	1	1	1	95
2	1	1	1	2	112
2	1	1	1	3	159
2	1	1	1	4	133
2	1	1	1	5	147
2	1	1	2	1	215
2	1	1	2	2	251
2	1	1	2	3	270
2	1	1	2	4	262
2	1	1	2	5	141
2	1	1	3	1	238
2	1	1	3	2	225
2	1	1	3	3	237
2	1	1	3	4	216
2	1	1	3	5	255
2	1	2	1	1	120
2	1	2	1	2	76
2	1	2	1	3	107
2	1	2	1	4	150
2	1	2	1	5	139
2	1	2	2	1	116
2	1	2	2	2	145
2	1	2	2	3	204
2	1	2	2	4	255
2	1	2	2	5	214
2	1	2	3	1	191
2	1	2	3	2	255
2	1	2	3	3	172
2	1	2	3	4	196
2	1	2	3	5	199
2	1	3	1	1	108
2	1	3	1	2	74
2	1	3	1	3	112
2	1	3	1	4	76
2	1	3	1	5	117
2	1	3	2	1	114
2	1	3	2	2	97
2	1	3	2	3	127
2	1	3	2	4	150
2	1	3	2	5	101
2	1	3	3	1	221
2	1	3	3	2	115
2	1	3	3	3	135
2	1	3	3	4	157
2	1	3	3	5	215
2	2	1	1	1	178
2	2	1	1	2	91
2	2	1	1	3	154
2	2	1	1	4	78
2	2	1	1	5	104
2	2	1	2	1	145
2	2	1	2	2	173
2	2	1	2	3	184
2	2	1	2	4	243
2	2	1	2	5	225
2	2	1	3	1	221
2	2	1	3	2	155
2	2	1	3	3	97
2	2	1	3	4	222
2	2	1	3	5	305
2	2	2	1	1	41
2	2	2	1	2	55
2	2	2	1	3	150
2	2	2	1	4	75
2	2	2	1	5	94
2	2	2	2	1	115
2	2	2	2	2	208
2	2	2	2	3	130
2	2	2	2	4	154
2	2	2	2	5	157
2	2	2	3	1	159
2	2	2	3	2	133
2	2	2	3	3	91
2	2	2	3	4	141
2	2	2	3	5	95
2	2	3	1	1	50
2	2	3	1	2	67
2	2	3	1	3	57
2	2	3	1	4	45
2	2	3	1	5	40
2	2	3	2	1	125
2	2	3	2	2	95
2	2	3	2	3	125
2	2	3	2	4	194
2	2	3	2	5	112
2	2	3	3	1	70
2	2	3	3	2	131
2	2	3	3	3	132
2	2	3	3	4	10
2	2	3	3	5	185

TABLE B-4. Thirty Day Values

1	1	1	1	1	306
1	1	1	1	2	345
1	1	1	1	3	[illegible]
1	1	1	1	4	332
1	1	1	1	5	353
1	1	1	2	1	[illegible]
1	1	1	2	2	677
1	1	1	2	3	457
1	1	1	2	4	674
1	1	1	2	5	[illegible]
1	1	1	3	1	[illegible]
1	1	1	3	2	[illegible]
1	1	1	3	3	[illegible]
1	1	1	3	4	[illegible]
1	1	1	3	5	571
1	1	2	1	1	[illegible]
1	1	2	1	2	[illegible]
1	1	2	1	3	[illegible]
1	1	2	1	4	[illegible]
1	1	2	1	5	[illegible]
1	1	2	2	1	[illegible]
1	1	2	2	2	344
1	1	2	2	3	446
1	1	2	2	4	331
1	1	2	2	5	[illegible]
1	1	2	3	1	554
1	1	2	3	2	[illegible]
1	1	2	3	3	471
1	1	2	3	4	629
1	1	2	3	5	[illegible]
1	1	3	1	1	[illegible]
1	1	3	1	2	[illegible]
1	1	3	1	3	[illegible]
1	1	3	1	4	147
1	1	3	1	5	196
1	1	3	2	1	[illegible]
1	1	3	2	2	275
1	1	3	2	3	[illegible]
1	1	3	2	4	[illegible]
1	1	3	2	5	[illegible]
1	1	3	3	1	[illegible]
1	1	3	3	2	416
1	1	3	3	3	[illegible]
1	1	3	3	4	[illegible]
1	1	3	3	5	[illegible]
1	2	1	1	1	[illegible]
1	2	1	1	2	[illegible]
1	2	1	1	3	[illegible]
1	2	1	1	4	[illegible]
1	2	1	1	5	[illegible]
1	2	1	2	1	547
1	2	1	2	2	[illegible]
1	2	1	2	3	400
1	2	1	2	4	[illegible]
1	2	1	2	5	334
1	2	1	3	1	[illegible]
1	2	1	3	2	[illegible]
1	2	1	3	3	690
1	2	1	3	4	[illegible]
1	2	1	3	5	[illegible]
1	2	2	1	1	[illegible]
1	2	2	1	2	151
1	2	2	1	3	[illegible]
1	2	2	1	4	[illegible]
1	2	2	1	5	[illegible]
1	2	2	2	1	[illegible]
1	2	2	2	2	251
1	2	2	2	3	415
1	2	2	2	4	444
1	2	2	2	5	[illegible]
1	2	2	3	1	[illegible]
1	2	2	3	2	595
1	2	2	3	3	535
1	2	2	3	4	521
1	2	2	3	5	412
1	2	3	1	1	[illegible]
1	2	3	1	2	151
1	2	3	1	3	[illegible]
1	2	3	1	4	[illegible]
1	2	3	1	5	[illegible]
1	2	3	2	1	297
1	2	3	2	2	205
1	2	3	2	3	[illegible]
1	2	3	2	4	[illegible]
1	2	3	2	5	[illegible]
1	2	3	3	1	[illegible]
1	2	3	3	2	[illegible]
1	2	3	3	3	415
1	2	3	3	4	[illegible]
1	2	3	3	5	[illegible]

TABLE B-4. Continued

2	1	1	1	1	111
2	1	1	1	2	227
2	1	1	1	3	[illegible]
2	1	1	1	4	[illegible]
2	1	1	1	5	152
2	1	1	2	1	417
2	1	1	2	2	463
2	1	1	2	3	467
2	1	1	2	4	557
2	1	1	2	5	[illegible]
2	1	1	3	1	507
2	1	1	3	2	726
2	1	1	3	3	629
2	1	1	3	4	531
2	1	1	3	5	[illegible]
2	1	2	1	1	[illegible]
2	1	2	1	2	[illegible]
2	1	2	1	3	231
2	1	2	1	4	272
2	1	2	1	5	[illegible]
2	1	2	2	1	[illegible]
2	1	2	2	2	[illegible]
2	1	2	2	3	285
2	1	2	2	4	[illegible]
2	1	2	2	5	416
2	1	2	3	1	[illegible]
2	1	2	3	2	531
2	1	2	3	3	[illegible]
2	1	2	3	4	725
2	1	2	3	5	497
2	1	3	1	1	199
2	1	3	1	2	151
2	1	3	1	3	174
2	1	3	1	4	159
2	1	3	1	5	210
2	1	3	2	1	227
2	1	3	2	2	[illegible]
2	1	3	2	3	[illegible]
2	1	3	2	4	361
2	1	3	2	5	[illegible]
2	1	3	3	1	369
2	1	3	3	2	259
2	1	3	3	3	[illegible]
2	1	3	3	4	[illegible]
2	1	3	3	5	376
2	2	1	1	1	[illegible]
2	2	1	1	2	165
2	2	1	1	3	[illegible]
2	2	1	1	4	169
2	2	1	1	5	237
2	2	1	2	1	179
2	2	1	2	2	310
2	2	1	2	3	317
2	2	1	2	4	[illegible]
2	2	1	2	5	417
2	2	1	3	1	[illegible]
2	2	1	3	2	[illegible]
2	2	1	3	3	219
2	2	1	3	4	327
2	2	1	3	5	[illegible]
2	2	2	1	1	134
2	2	2	1	2	[illegible]
2	2	2	1	3	[illegible]
2	2	2	1	4	[illegible]
2	2	2	1	5	175
2	2	2	2	1	[illegible]
2	2	2	2	2	[illegible]
2	2	2	2	3	[illegible]
2	2	2	2	4	223
2	2	2	2	5	205
2	2	2	3	1	[illegible]
2	2	2	3	2	249
2	2	2	3	3	[illegible]
2	2	2	3	4	[illegible]
2	2	2	3	5	321
2	2	3	1	1	[illegible]
2	2	3	1	2	[illegible]
2	2	3	1	3	117
2	2	3	1	4	[illegible]
2	2	3	1	5	[illegible]
2	2	3	2	1	[illegible]
2	2	3	2	2	137
2	2	3	2	3	[illegible]
2	2	3	2	4	[illegible]
2	2	3	2	5	[illegible]
2	2	3	3	1	[illegible]
2	2	3	3	2	271
2	2	3	3	3	210
2	2	3	3	4	172
2	2	3	3	5	[illegible]

APPENDIX C

SPSS OUTPUT

The tables in this appendix contain the Analysis of Variance, Multiple Classification Analysis, and other statistical information used in this thesis. Each successive group of six tables pertains to a designated analysis point.

TABLE C-1. ANOVA at the Three Day Analysis Point

[illegible] SUPPLY [illegible]

FILE [illegible] (CREATION DATE = [illegible]/77)

[illegible]

BY [illegible]P [illegible] V[illegible]
[illegible]UM [illegible]
[illegible]PL [illegible]PL[illegible]
BU[illegible]H [illegible] B[illegible]Y [illegible]

SOURCE OF VARIATION			SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS			57377.535	6	9562.93	55.384	.[illegible]
[illegible]P			41262.297	2	20631.148	119.775	.[illegible]
[illegible]UM			[illegible]329.73[illegible]	2	5664.863	32.8[illegible]8	.[illegible]
[illegible]PL			3.756	1	3.756	.022	.883
BU[illegible]H			4681.797	1	4681.797	27.115	0.000
2-WAY [illegible]			[illegible].[illegible]36	12	372.379	2.157	.[illegible]14
[illegible]P	[illegible]UM		[illegible]68.[illegible]69	4	[illegible].[illegible]42	.823	.513
[illegible]P	[illegible]PL		[illegible]9.[illegible]78	2	[illegible].529	2.43[illegible]	.[illegible]92
[illegible]P	BU[illegible]H		2255.7	2	1127.85	6.532	.[illegible]
[illegible]UM	[illegible]PL		663.244	2	331.622	1.921	.15[illegible]
[illegible]UM	BU[illegible]H		368.933	2	184.467	1.068	.346
[illegible]PL	BU[illegible]H		145.8	1	145.8	.844	.35[illegible]
3-WAY [illegible]			5685.113	12	473.759	2.744	.[illegible]
[illegible]P	[illegible]UM	[illegible]PL	1161.326	4	29[illegible].331	1.681	.157
[illegible]P	[illegible]UM	BU[illegible]H	16[illegible].767	4	[illegible].142	.232	.92[illegible]
[illegible]P	[illegible]PL	BU[illegible]H	3611.632	2	[illegible]8[illegible]5.816	1[illegible].458	.[illegible]
[illegible]UM	[illegible]PL	BU[illegible]H	751.596	2	375.798	2.176	.117
4-WAY [illegible]			1674.198	4	418.547	2.424	.[illegible]51
[illegible]P	[illegible]UM BU[illegible]H	[illegible]PL	[illegible]74.228	4	4[illegible]3.557	2.424	.[illegible]51
EXPLAINED			69577.313	35	1987.938	11.513	0.[illegible]
RESIDUAL			24863.938	144	172.666		
TOTAL			94441.75	179	527.[illegible]7		

TABLE C-2. MCA at the Three Day Analysis Point

[illegible] Z

FILE [illegible] ([illegible] DATE = 12/2[illegible]/7[illegible])

[illegible] Y S [illegible]

[illegible]	[illegible]LS	[illegible] V[illegible]
BY	[illegible]P	NUMBER [illegible] Y
	[illegible]	[illegible] V[illegible]H
	P[illegible]	[illegible]
	BUSH	[illegible] B[illegible] Y [illegible] BRU[illegible]H

GRAND MEAN = [illegible].53

VARIABLE + CATEGORY	N	UNADJUSTED DEV'N	ETA	ADJUSTED FOR INDEPENDENTS DEV'N	BETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV'N	BETA
[illegible]							
1 1 [illegible] DAY	5[illegible]	-19.53		-19.53			
2 2 [illegible]PS	[illegible]	[illegible].12		2.12			
3 3 [illegible]PS	5	17.42		17.[illegible]			
			.55		.66		
NUM							
1 NU[illegible] 15	5	[illegible].72		[illegible].73			
2 NU[illegible] 12	5[illegible]	-[illegible]		-[illegible].3			
3 NU[illegible] 9	6[illegible]	-9.7		-9.7			
			[illegible].25		.35		
REPL							
1 [illegible] 3	[illegible]	.14		.14			
2 [illegible] 3	9[illegible]	.14		.14			
			.1		.[illegible]		
BUSH							
1 [illegible] .1	[illegible]	5.[illegible]		5.[illegible]			
2 [illegible] .2	9	-5.[illegible]		-5.[illegible]			
			.22		.22		

MULTIPLE R SQUARED .6[illegible]8

MULTIPLE R .779

TABLE C-3. One Way ANOVA at the Three Day Analysis Point for INUM

INTERDICTION OF RESUPPLY IN CZ 12/19/77 PAGE 2

FILE NONAME (CREATION DATE = 12/19/77)

- O N E W A Y -

VARIABLE TOTAL3 DEPEN VAR

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	2	11329.6504	5664.8242	12.064	[illegible]
LINEAR TERM	1	11329.6328	11329.6328	24.128	[illegible]
DEV. FROM LINEAR	1	0.0175	0.0175	0.000	0.9951
WITHIN GROUPS	177	83113.8[illegible]9	469.5693		
TOTAL	179	94443.4375			

GROUP	COUNT	MEAN	STANDARD DEVIATION	STANDARD ERROR	MINIMUM	MAXIMUM	95 PCT CONF INT FOR MEAN
GRP01	60	55.3667	24.2[illegible]95	3.1254	13.[illegible]	117.[illegible]	49.1127 TO 61.62[illegible]6
GRP02	60	45.6000	22.2552	2.8731	1[illegible].0000	93.[illegible]	39.85[illegible]9 TO 5[illegible].3491
GRP03	60	35.9333	18.[illegible]919	2.3357	4.[illegible]	71.[illegible]	31.2597 TO 4[illegible].6[illegible]69
TOTAL	180	45.6333	22.9699	1.7121	4.0000	117.0000	42.2549 TO 49.[illegible]118
FIXED EFFECTS MODEL			21.6696	1.6152			42.4459 TO 48.82[illegible]8
RANDOM EFFECTS MODEL			9.7167	5.6[illegible]99			21.4954 TO 69.7712

TABLE C-4. Multiple Range Test at the Three Day Analysis Point for INUM

```
INTERDICTION OF RESUPPLY IN CZ                                      12/19/77        PAGE    3
FILE   NONAME   (CREATION DATE = 12/19/77)
- - - - - - - - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - - - - - - - - -

      VARIABLE   TOTAL3     DEPEN VAR

MULTIPLE RANGE TEST

SCHEFFE PROCEDURE
RANGES FOR THE 0.050 LEVEL -

           3.49  3.49

THE RANGES ABOVE ARE TABLE RANGES.  THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
         15.3227 * RANGE * SQRT(1/N(I) + 1/N(J))

  HOMOGENEOUS SUBSETS    (SUBSETS OF GROUPS, WHOSE HIGHEST AND LOWEST MEANS DO NOT DIFFER BY MORE THAN THE SHORTEST
                          SIGNIFICANT RANGE FOR A SUBSET OF THAT SIZE)

SUBSET  1

GROUP        GRP 3         GRP 2
MEAN        35.9333       45.0000
- - - - - - - - - - - - - - - - -

SUBSET  2

GROUP        GRP 1
MEAN        55.3667
- - - - - - - - - - -
```

TABLE C-5. One Way ANOVA at the Three Day Analysis Point for TRIP

INTERDICTION OF RESUPPLY IN CZ
FILE NONAME (CREATION DATE = 12/19/77) 12/19/77 PAGE 2

- - - - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - - - - -

VARIABLE TOTAL3 DEPEN VAR

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	2	41362.2562	20681.1250	68.961	0.0000
LINEAR TERM	1	40959.0742	40959.0742	136.578	[illegible]
DEV. FROM LINEAR	1	403.1820	403.1819	1.344	0.2478
WITHIN GROUPS	177	53081.2938	299.8943		
TOTAL	179	94443.5000			

GROUP	COUNT	MEAN	STANDARD DEVIATION	STANDARD ERROR	MINIMUM	MAXIMUM	95 PCT CONF INT FOR MEAN
GRP01	60	26.1[illegible]	8.73[illegible]8	1.1271	4.[illegible]	42.[illegible]	23.8446 TO 28.3554
GRP02	60	47.7500	16.7480	2.1622	11.0000	87.0000	43.4235 TO 52.[illegible]764
GRP03	60	63.0500	23.3[illegible]15	3.0[illegible]82	16.0000	117.0000	57.[illegible]3[illegible]6 TO 69.[illegible]694
TOTAL	180	45.6333	22.9699	1.7121	4.[illegible]	117.0000	42.2549 TO 49.0118
FIXED EFFECTS MODEL			17.3175	1.2908			43.[illegible]861 TO 48.18[illegible]6
RANDOM EFFECTS MODEL			18.5657	1[illegible].7189			[illegible].4869 TO 91.7536

TABLE C-6. Multiple Range Test at the Three Day Analysis Point for TRIP

```
INTERDICTION OF RESUPPLY IN CZ                                    12/19/77      PAGE   3
FILE   NINAME   (CREATION DATE = 12/19/77)
- - - - - - - - - - - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - - - - - - - - - - -

      VARIABLE  TOTAL3      DEPEN VAR

MULTIPLE RANGE TEST

SCHEFFE PROCEDURE
RANGES FOR THE 0.050 LEVEL -

            3.49  3.49

THE RANGES ABOVE ARE TABLE RANGES.  THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
        12.2453 * RANGE * SQRT(1/N(I) + 1/N(J))

  HOMOGENEOUS SUBSETS   (SUBSETS OF GROUPS, WHOSE HIGHEST AND LOWEST MEANS DO NOT DIFFER BY MORE THAN THE SHORTEST
                         SIGNIFICANT RANGE FOR A SUBSET OF THAT SIZE)

SUBSET  1

GROUP          GRP 1
MEAN          26.1000
- - - - - - - - - - -
SUBSET  2

GROUP          GRP 2
MEAN          47.75
- - - - - - - - - - -
SUBSET  3

GROUP          GRP 3
MEAN          63.75
- - - - - - - - - - -
```

TABLE C-7. ANOVA at the Five Day Analysis Point

* * * * * * * * * * A N A L Y S I S   O F   V A R I A N C E * * * * * * * * * *

	TOTAL5	DEPEN VAR
BY	TRIP	NUMBER OF TRIPS PER DAY
	INUM	INITIAL NUM OF VEH
	BUSH	PROBABILITY OF AMBUSH
	REPL	REPLACEMENT RATE

* *

SOURCE OF VARIATION			SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS			125481.313	6	20913.551	48.2[illegible]1	0.[illegible]
TRIP			81391.875	2	40695.938	93.794	0.[illegible]
INUM			26523.5[illegible]8	2	13261.754	3[illegible].565	0.[illegible]
BUSH			17287.199	1	17287.199	39.843	0.[illegible]
REPL			278.755	1	278.755	0.642	0.424
2-WAY INTERACTIONS			12718.688	13	978.36[illegible]	2.255	0.[illegible]1[illegible]
TRIP	INUM		1301.994	4	325.499	0.750	0.559
TRIP	BUSH		6951.297	2	348[illegible].648	8.[illegible]22	0.[illegible]
TRIP	REPL		1461.411	2	73[illegible].7[illegible]5	1.684	[illegible].189
INUM	BUSH		21[illegible]7.733	2	1[illegible]53.866	2.429	0.[illegible]92
INUM	REPL		664.[illegible]44	2	332.[illegible]22	[illegible].765	[illegible].467
BUSH	REPL		222.222	1	222.222	0.512	0.475
3-WAY INTERACTIONS			1[illegible]558.875	12	879.9[illegible]6	2.[illegible]28	0.[illegible]26
TRIP	INUM	BUSH	347.969	4	86.992	[illegible].2[illegible]	[illegible].938
TRIP	INUM	REPL	1593.195	4	398.299	0.918	0.455
TRIP	BUSH	REPL	6[illegible]93.676	2	3[illegible]46.838	7.[illegible]22	[illegible].[illegible]1
INUM	BUSH	REPL	2524.[illegible]32	2	1262.[illegible]16	2.9[illegible]9	[illegible].[illegible]58
4-WAY INTERACTIONS			5925.875	4	1481.469	3.414	0.011
TRIP	INUM REPL	BUSH	5925.836	4	1481.459	3.414	0.[illegible]11
EXPLAINED			154684.750	35	4419.563	10.186	0.[illegible]
RESIDUAL			62479.563	144	433.886		
TOTAL			217164.313	179	1213.208		

TABLE C-8. MCA at the Five Day Analysis Point

* * * M U L T I P L E C L A S S I F I C A T I O N A N A L Y S I S * * *

	TOTAL5	DEPEN VAR
BY	TRIP	NUMBER OF TRIPS PER DAY
	INUM	INITIAL NUM OF VEH
	BUSH	PROBABILITY OF AMBUSH
	REPL	REPLACEMENT RATE

GRAND MEAN = 69.31

VARIABLE + CATEGORY	N	UNADJUSTED DEV'N	ETA	ADJUSTED FOR INDEPENDENTS DEV'N	BETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV'N	BETA
TRIP							
1 1 TRIP PER DAY	60	-27.88		-27.88			
2 2 TRIPS	60	4.17		4.17			
3 3 TRIPS	60	23.71		23.71			
			.61		0.61		
INUM							
1 NUM IS 15	60	14.26		14.26			
2 NUM IS 12	60	1.16		1.16			
3 NUM IS 9	60	-15.41		-15.41			
			0.35		0.35		
BUSH							
1 PA IS .1	90	9.80		9.80			
2 PA IS .2	90	-9.8		-9.8			
			.28		.28		
REPL							
1 RATE IS 3	90	1.24		1.24			
2 RATE IS 8	90	-1.24		-1.24			
			0.04		0.04		
MULTIPLE R SQUARED					0.578		
MULTIPLE R					0.760		

TABLE C-9. One Way ANOVA at the Five Day Analysis Point for INUM

INTERDICTION OF RESUPPLY IN CZ — 12/19/77 — PAGE 2

FILE NONAME (CREATION DATE = 12/19/77)

- - - - - - - - - - O N E W A Y - - - - - - - - - -

VARIABLE TOTALS DEPEN VAR

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	2	26523.6423	13261.8223	12.313	[illegible]
LINEAR TERM	1	26403.2227	26403.2227	24.514	0.0000
DEV. FROM LINEAR	1	12[illegible].4196	12[illegible].4196	0.112	0.7385
WITHIN GROUPS	177	19[illegible]644.1836	1077.0857		
TOTAL	179	217167.8125			

GROUP	COUNT	MEAN	STANDARD DEVIATION	STANDARD ERROR	MINIMUM	MAXIMUM	95 PCT CONF INT FOR MEAN		
GRP01	60	83.5667	37.6636	4.8623	21.0000	185.0000	73.5371	TO	93.2962
GRP02	60	7[illegible].4667	32.7251	4.2248	2[illegible]	149.[illegible]	62.[illegible]129	TO	78.92[illegible]4
GRP03	60	53.9[illegible]	27.2357	3.5161	6.[illegible]	122.[illegible]	46.8643	TO	60.9357
TOTAL	180	69.3111	34.8314	2.5962	6.0000	185.0000	64.188[illegible]	TO	74.4342
FIXED EFFECTS MODEL			32.819[illegible]	2.4462			64.4837	TO	74.1385
RANDOM EFFECTS MODEL			14.8671	8.5835			32.3789	TO	1[illegible]6.2433

TABLE C-10. Multiple Range Test at the Five Day Analysis Point for INUM

```
INTERACTION OF RESUPPLY IN CZ                                          12/19/77        PAGE   3
FILE    NONAME    (CREATION DATE = 12/19/77)
------------------------------------ O N E W A Y ------------------------------------

      VARIABLE  TOTAL5      DEPEN VAR

MULTIPLE RANGE TEST

SCHEFFE PROCEDURE
RANGES FOR THE 0.050 LEVEL -

          3.49  3.49

THE RANGES ABOVE ARE TABLE RANGES.  THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
           23.2165 * RANGE * SQRT(1/N(I) + 1/N(J))

  HOMOGENEOUS SUBSETS   (SUBSETS OF GROUPS, WHOSE HIGHEST AND LOWEST MEANS DO NOT DIFFER BY MORE THAN THE SHORTEST
                         SIGNIFICANT RANGE FOR A SUBSET OF THAT SIZE)

SUBSET  1

GROUP       GRP03
MEAN        53.9000
- - - - - - - - - - -

SUBSET  2

GROUP       GRP02         GRP01
MEAN        70.4667       83.5667
- - - - - - - - - - - - - - - - - -
```

TABLE C-11. One Way ANOVA at the Five Day Analysis Point for TRIP

INTERDICTION OF RESUPPLY IN CZ 12/19/77 PAGE 2

FILE NONAME (CREATION DATE = 12/19/77)

- O N E W A Y -

VARIABLE TOTAL5 DEPEN VAR

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	2	81391.9565	40695.9766	53.[illegible]52	.[illegible]
LINEAR TERM	1	79825.0000	79825.0000	104.061	0.0000
DEV. FROM LINEAR	1	1566.9565	1566.9563	2.[illegible]43	.1547
WITHIN GROUPS	177	135775.9844	767.0959		
TOTAL	179	217167.9375			

GROUP	COUNT	MEAN	STANDARD DEVIATION	STANDARD ERROR	MINIMUM	MAXIMUM	95 PCT CONF INT FOR MEAN
GRP01	60	41.4333	14.4613	1.8669	6.0000	69.0000	37.6976 TO 45.1691
GRP02	60	73.4833	26.5652	3.4296	25.[illegible]	135.[illegible]	66.62[illegible]8 TO 8[illegible].3458
GRP03	60	93.0167	37.2350	4.8070	23.0000	185.0000	83.3978 TO 102.6355
TOTAL	180	69.3111	34.8314	2.5962	6.0000	185.0000	64.188[illegible] TO 74.4342
FIXED EFFECTS MODEL			27.6965	2.[illegible]644			65.2372 TO 73.3851
RANDOM EFFECTS MODEL			26.0435	15.0362			4.6147 TO 134.[illegible]75

TABLE C-12. Multiple Range Test at the Five Day Analysis Point for TRIP

```
INTERDICTION OF RESUPPLY IN CZ                                        12/19/77        PAGE    3
FILE   NONAME   (CREATION DATE = 12/19/77)
- - - - - - - - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - - - - - - - - -

      VARIABLE  TOTAL5      DEPEN VAR

MULTIPLE RANGE TEST

SCHEFFE PROCEDURE
RANGES FOR THE 0.050 LEVEL -

          3.49  3.49

THE RANGES ABOVE ARE TABLE RANGES.  THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
        19.5844 * RANGE * SQRT(1/N(I) + 1/N(J))

  HOMOGENEOUS SUBSETS   (SUBSETS OF GROUPS, WHOSE HIGHEST AND LOWEST MEANS DO NOT DIFFER BY MORE THAN THE SHORTEST
                          SIGNIFICANT RANGE FOR A SUBSET OF THAT SIZE)

SUBSET  1

GROUP        GRP 1
MEAN        41.4333
- - - - - - - - - - -

SUBSET  2

GROUP        GRP 2
MEAN        73.4833
- - - - - - - - - - -

SUBSET  3

GROUP        GRP 3
MEAN        93.0167
- - - - - - - - - - -
```

TABLE C-13. ANOVA at the Fifteen Day Analysis Point

INTERDICTION OF RESUPPLY IN CZ

FILE NONAME (CREATION DATE = 12/19/77)

* * * * * * * * * * A N A L Y S I S O F V A R I A N C E * * * * * * * * * *

	TOT15	DEPEN VAR
BY	TRIP	NUMBER OF TRIPS PER DAY
	INUM	INITIAL NUM OF VEH
	BUSH	PROBABILITY OF AMBUSH
	REPL	REPLACEMENT RATE

* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	823609.563	6	137268.250	84.139	0.000
TRIP	429269.375	2	214634.938	131.561	0.000
INUM	217[illegible]4[illegible].188	2	1[illegible]852[illegible].[illegible]63	66.518	[illegible]
BUSH	106969.688	1	106969.688	65.567	0.000
REPL	70329.750	1	70329.750	43.1[illegible]9	[illegible]
2-WAY INTERACTIONS	72753.438	13	5596.418	3.43[illegible]	[illegible]
TRIP INUM	11288.367	4	2822.092	1.73[illegible]	0.147
TRIP BUSH	44113.91[illegible]	2	22[illegible]56.953	13.52[illegible]	[illegible]
TRIP REPL	11443.598	2	5721.797	3.5[illegible]7	0.033
INUM BUSH	3[illegible]55.344	2	1527.672	[illegible].936	0.394
INUM REPL	2816.633	2	14[illegible]8.317	[illegible].863	[illegible].424
BUSH REPL	35.556	1	35.556	0.022	0.883
3-WAY INTERACTIONS	7635.625	12	636.3[illegible]2	[illegible].39[illegible]	[illegible].965
TRIP INUM BUSH	2624.684	4	65[illegible].171	[illegible].4[illegible]2	[illegible].8[illegible]7
TRIP INUM REPL	2655.62[illegible]	4	663.905	0.4[illegible]7	0.8[illegible]3
TRIP BUSH REPL	1344.852	2	672.426	[illegible].412	[illegible].663
INUM BUSH REPL	1[illegible]10.463	2	505.231	0.31[illegible]	0.734
4-WAY INTERACTIONS	2[illegible]83.625	4	52[illegible].906	0.319	[illegible].865
TRIP INUM BUSH REPL	2[illegible]83.667	4	52[illegible].917	[illegible].319	[illegible].865
EXPLAINED	9[illegible]6[illegible]82.25[illegible]	35	25888.[illegible]63	15.868	[illegible]
RESIDUAL	234928.75[illegible]	144	1631.449		
TOTAL	1141[illegible]11.[illegible]	179	6374.359		

TABLE C-14. MCA at the Fifteen Day Analysis Point

INTERDICTION OF RESUPPLY IN CZ

FILE NONAME (CREATION DATE = 12/19/77)

```
* * *   M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S   * * *
            YOT15     DEPEN VAR
      BY    TRIP      NUMBER OF TRIPS PER DAY
            INUM      INITIAL NUM OF VEH
            BUSH      PROBABILITY OF AMBUSH
            REPL      REPLACEMENT RATE
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

GRAND MEAN = 177.34

VARIABLE + CATEGORY	N	UNADJUSTED DEV'N	ETA	ADJUSTED FOR INDEPENDENTS DEV'N	BETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV'N	BETA
TRIP							
1 1 TRIP PER DAY	60	-65.74		-65.74			
2 2 TRIPS	60	14.56		14.56			
3 3 TRIPS	60	51.19		51.19			
			0.61		0.61		
INUM							
1 NUM IS 15	60	43.71		43.71			
2 NUM IS 12	60	-2.46		-2.46			
3 NUM IS 9	60	-41.24		-41.24			
			0.44		0.44		
BUSH							
1 PA IS .1	90	24.38		24.38			
2 PA IS .2	90	-24.38		-24.38			
			.31		.31		
REPL							
1 RATE IS 5	90	19.77		19.77			
2 RATE IS 8	90	-19.77		-19.77			
			0.25		0.25		
MULTIPLE R SQUARED					0.722		
MULTIPLE R					0.850		

TABLE C-15. One Way ANOVA at the Fifteen Day Analysis Point for INUM

INTERDICTION OF RESUPPLY IN CZ 12/19/77 PAGE 3

FILE NONAME (CREATION DATE = 12/19/77)

- - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - - -

VARIABLE TOT15 DEPEN VAR

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	2	217[illegible].2[illegible]21	1[illegible]852[illegible].[illegible]625	2[illegible].788	[illegible]
LINEAR TERM	1	216495.[illegible]625	216495.[illegible]625	[illegible].472	[illegible]
DEV. FROM LINEAR	1	545.1396	545.1394	[illegible].1[illegible]4	.747[illegible]
WITHIN GROUPS	177	923982.5625	522[illegible].2383		
TOTAL	179	1141[illegible]22.[illegible]			

GROUP	COUNT	MEAN	STANDARD DEVIATION	STANDARD ERROR	MINIMUM	MAXIMUM	95 PCT CONF INT FOR MEAN		
GRP01	6[illegible]	221.[illegible]	87.[illegible]357	11.2492	78.[illegible]	452.[illegible]	198.54[illegible]5	TO	243.5595
GRP02	6[illegible]	174.8833	68.2938	8.8167	59.[illegible]	351.[illegible]	157.2412	TO	192.5255
GRP03	[illegible]	136.1[illegible]	58.3441	7.5322	29.[illegible]	274.[illegible]	121.[illegible]	TO	15[illegible].17[illegible]9
TOTAL	18[illegible]	177.3444	79.84[illegible]	5.95[illegible]9	29.[illegible]	452.[illegible]	165.6[illegible]15	TO	189.[illegible]874
FIXED EFFECTS MODEL			72.2512	5.3853			166.7168	TO	187.9721
RANDOM EFFECTS MODEL			42.5284	24.5538			71.6968	TO	282.9919

TABLE C-16. Multiple Range Test at the Fifteen Day Analysis Point for INUM

```
INTERDICTION OF RESUPPLY IN CZ                                          12/19/77       PAGE   4
FILE   NONAME   (CREATION DATE = 12/19/77)
- - - - - - - - - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - - - - - -

      VARIABLE   TOT15       DEPEN VAR

MULTIPLE RANGE TEST

SCHEFFE PROCEDURE
RANGES FOR THE  .05 LEVEL -

            3.49  3.49

THE RANGES ABOVE ARE TABLE RANGES.  THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
        51.0893 * RANGE * SQRT(1/N(I) + 1/N(J))

  HOMOGENEOUS SUBSETS   (SUBSETS OF GROUPS, WHOSE HIGHEST AND LOWEST MEANS DO NOT DIFFER BY MORE THAN THE SHORTEST
                         SIGNIFICANT RANGE FOR A SUBSET OF THAT SIZE)

SUBSET  1

GROUP       GRP03
MEAN      136.1

SUBSET  2

GROUP       GRP02
MEAN      174.8833

SUBSET  3

GROUP       GRP01
MEAN      221.  5
```

TABLE C-17. One Way ANOVA at the Fifteen Day Analysis Point for TRIP

INTERDICTION OF RESUPPLY IN CZ　　　　12/19/77　　　　PAGE 3

FILE NONAME (CREATION DATE = 12/19/77)

- O N E W A Y -

VARIABLE TOT15　　DEPEN VAR

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	2	429269.9169	214634.9375	53.376	0.[illegible]
LINEAR TERM	1	41[illegible]2.125	41[illegible]2.125	1[illegible]2.1	[illegible]
DEV. FROM LINEAR	1	19[illegible]67.7919	19[illegible]57.7891	4.742	0.03[illegible]8
WITHIN GROUPS	177	711753.5625	4[illegible]21.2[illegible]65		
TOTAL	[illegible]79	11411023.[illegible]			

GROUP	COUNT	MEAN	STANDARD DEVIATION	STANDARD ERROR	MINIMUM	MAXIMUM	95 PCT CONF INT FOR MEAN		
GRP01	6[illegible]	111.6[illegible]	38.9576	5.[illegible]294	29.[illegible]	195.[illegible]	1[illegible]1.5362	TO	121.6638
GRP02	6[illegible]	19[illegible].9[illegible]	61.893[illegible]	7.99[illegible]4	85.[illegible]	279.[illegible]	175.9[illegible]3	TO	2[illegible]7.8396
GRP03	6[illegible]	228.5333	81.9462	1[illegible].5792	91.[illegible]	452.[illegible]	2[illegible]7.3644	TO	249.7[illegible]23
TOTAL	18	177.3444	79.8403	5.9509	29.0000	452.0[illegible]	165.[illegible]15	TO	189.[illegible]874
FIXED EFFECTS MODEL			63.413[illegible]	4.7265			168.[illegible]168	TO	186.672[illegible]
RANDOM EFFECTS MODEL			59.81[illegible]1	34.5314			28.7663	TO	325.9224

TABLE C-18. Multiple Range Test at the Fifteen Day Analysis Point for TRIP

```
INTERDICTION OF RESUPPLY IN CZ                                          12/19/77        PAGE   4
FILE    NONAME    (CREATION DATE = 12/19/77)
- - - - - - - - - - - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - - - - - - - - - - - -

      VARIABLE  TOT15       DEPEN VAR

MULTIPLE RANGE TEST

SCHEFFE PROCEDURE
RANGES FOR THE 0.050 LEVEL -

           3.49  3.49

THE RANGES ABOVE ARE TABLE RANGES.  THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
         44.8398 * RANGE * SQRT(1/N(I) + 1/N(J))

   HOMOGENEOUS SUBSETS    (SUBSETS OF GROUPS, WHOSE HIGHEST AND LOWEST MEANS DO NOT DIFFER BY MORE THAN THE SHORTEST
                           SIGNIFICANT RANGE FOR A SUBSET OF THAT SIZE)

SUBSET  1

GROUP        GRP 1
MEAN      111.6000
- - - - - - - - - - -

SUBSET  2

GROUP        GRP 2
MEAN      191.9600
- - - - - - - - - - -

SUBSET  3

GROUP        GRP 3
MEAN      228.5333
- - - - - - - - - - -
```

TABLE C-19. ANOVA at the Thirty Day Analysis Point

INTERDICTION OF RESUPPLY IN LZ

FILE NONAME (CREATION DATE = 12/19/77)

* * * * * * * * * * A N A L Y S I S O F V A R I A N C E * * * * * * * * * *

	TOTAL	DEPEN VAR
BY	BUSH	PROBABILITY OF AMBUSH
	REPL	REPLACEMENT RATE
	TRIP	NUMBER OF TRIPS PER DAY
	TNUM	INITIAL NUM OF VEH

* *

SOURCE OF VARIATION			SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS			3441708.000	6	573618.000	137.246	0.000
BUSH			457732.938	1	457732.938	1[illegible]9.519	0.000
REPL			386883.438	1	386883.438	92.567	0.000
TRIP			1666487.[illegible]	2	833243.5[illegible]	199.365	0.000
TNUM			93[illegible]6[illegible]5.5[illegible]	2	465302.750	111.330	0.000
2-WAY INTERACTIONS			404023.000	13	31078.691	7.436	0.000
BUSH	REPL		5678.449	1	5678.449	1.359	0.246
BUSH	TRIP		188893.125	2	94446.563	22.598	0.000
BUSH	TNUM		16108.676	2	8054.336	1.927	0.149
REPL	TRIP		64723.676	2	32361.836	7.743	0.001
REPL	TNUM		47941.141	2	23970.570	5.735	0.004
TRIP	TNUM		80677.563	4	20169.391	4.826	0.001
3-WAY INTERACTIONS			55922.000	12	4660.164	1.115	0.352
BUSH	REPL	TRIP	2153.961	2	1076.980	0.258	0.773
BUSH	REPL	TNUM	10176.555	2	5088.277	1.217	0.299
BUSH	TRIP	TNUM	10967.793	4	2741.948	0.656	0.624
REPL	TRIP	TNUM	32622.973	4	8155.742	1.951	0.105
4-WAY INTERACTIONS			14948.605	4	3737.151	0.894	0.469
BUSH	REPL TNUM	TRIP	14948.605	4	3737.151	0.894	0.469
EXPLAINED			3916601.000	35	111902.875	26.774	0.000
RESIDUAL			601847.000	144	4179.492		
TOTAL			4518448.[illegible]	179	25242.723		

TABLE C-20. MCA at the Thirty Day Analysis Point

INTERDICTION OF RESUPPLY IN CZ

FILE NONAME (CREATION DATE = 12/19/77)

* * * M U L T I P L E C L A S S I F I C A T I O N A N A L Y S I S * * *

	TOTAL	DEPEN VAR
BY	BUSH	PROBABILITY OF AMBUSH
	REPL	REPLACEMENT RATE
	TRIP	NUMBER OF TRIPS PER DAY
	INUM	INITIAL NUM OF VEH

* *

GRAND MEAN = 342.54

VARIABLE + CATEGORY	N	UNADJUSTED DEV'N	ETA	ADJUSTED FOR INDEPENDENTS DEV'N	BETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV'N	BETA
BUSH							
1 PA IS .1	90	50.43		50.43			
2 PA IS .2	90	-50.43		-50.43			
			.32		.32		
REPL							
1 RATE IS 3	90	46.36		46.36			
2 RATE IS 8	90	-46.36		-46.36			
			0.29		0.29		
TRIP							
1 1 TRIP PER DAY	60	-125.44		-125.44			
2 2 TRIPS	60	17.04		17.04			
3 3 TRIPS	60	108.39		108.39			
			0.61		0.61		
INUM							
1 NUM IS 15	60	89.66		89.66			
2 NUM IS 12	60	-3.29		-3.29			
3 NUM IS 9	60	-86.37		-86.37			
			.45		0.45		
MULTIPLE R SQUARED					0.762		
MULTIPLE R					0.873		

TABLE C-21. One Way ANOVA at the Thirty Day Analysis Point for INUM

INTERDICTION OF RESUPPLY IN CZ 12/19/77 PAGE 2

FILE NONAME (CREATION DATE = 12/19/77)

- O N E W A Y -

VARIABLE TOTAL DEPEN VAR

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	2	93[illegible]6.1252	4653[illegible]3.[illegible]625	22.955	[illegible]
LINEAR TERM	1	929633.3125	929633.3125	45.861	0.0001
DEV. FROM LINEAR	1	972.8127	972.8127	.48	.8266
WITHIN GROUPS	177	3587889.75[illegible]	20270.5625		
TOTAL	179	4518495.[illegible]			

GROUP	COUNT	MEAN	STANDARD DEVIATION	STANDARD ERROR	MINIMUM	MAXIMUM	95 PCT CONF INT FOR MEAN
GRP01	60	432.2[illegible]	173.9894	22.4619	165.[illegible]	888.[illegible]	387.2537 TO 477.146[illegible]
GRP02	60	339.25[illegible]	139.7614	18.[illegible]431	119.[illegible]	686.[illegible]	3[illegible]3.1458 TO 375.35[illegible]
GRP03	60	256.1665	1[illegible]4.9[illegible]	13.5438	87.[illegible]	543.[illegible]	229.[illegible]654 TO 283.2676
TOTAL	180	342.5589	158.8894	11.8422	87.[illegible]	888.[illegible]	319.17[illegible]4 TO 365.9[illegible]72
FIXED EFFECTS MODEL			142.3747	10.6120			321.5964 TO 363.481[illegible]
RANDOM EFFECTS MODEL			88.0628	5[illegible].8431			123.7764 TO 561.3[illegible]13

TABLE C-22. Multiple Range Test at the Thirty Day Analysis Point for INUM

```
INTERDICTION OF RESUPPLY IN CZ                                        12/19/77        PAGE   3
FILE    NONAME    (CREATION DATE = 12/19/77)
- - - - - - - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - - - - - - - -

      VARIABLE   TOTAL        DEPEN VAR

MULTIPLE RANGE TEST

SCHEFFE PROCEDURE
RANGES FOR THE 0.050 LEVEL -

           3.49   3.49

THE RANGES ABOVE ARE TABLE RANGES.  THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
      131.6741 * RANGE * SQRT(1/N(I) + 1/N(J))

  HOMOGENEOUS SUBSETS    (SUBSETS OF GROUPS, WHOSE HIGHEST AND LOWEST MEANS DO NOT DIFFER BY MORE THAN THE SHORTEST
                          SIGNIFICANT RANGE FOR A SUBSET OF THAT SIZE)

SUBSET   1

GROUP         GRP03
MEAN       256.1665
- - - - - - - - - -

SUBSET   2

GROUP         GRP02
MEAN       359.25
- - - - - - - - - -

SUBSET   3

GROUP         GRP01
MEAN       432.2[illegible]
- - - - - - - - - -
```

TABLE C-23. One Way ANOVA at the Thirty Day Analysis Point for TRIP

INTERDICTION OF RESUPPLY IN CZ 12/19/77 PAGE 2

FILE NONAME (CREATION DATE = 12/19/77)

- O N E W A Y -

VARIABLE TOTAL DEPEN VAR

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	2	1666483.3196	833241.6250	51.712	0.0000
LINEAR TERM	1	164[illegible]338.[illegible]	164[illegible]338.[illegible]	1[illegible]1.8[illegible]2	[illegible]
DEV. FROM LINEAR	1	26145.3196	26145.3164	[illegible].623	[illegible].2[illegible]44
WITHIN GROUPS	177	2852[illegible]17.875[illegible]	16113.[illegible]938		
TOTAL	179	45[illegible]8501.[illegible]			

GROUP	COUNT	MEAN	STANDARD DEVIATION	STANDARD ERROR	MINIMUM	MAXIMUM	95 PCT CONF INT FOR MEAN		
GRP01	6[illegible]	217.1[illegible]	65.2897	8.4289	87.[illegible]	353.0000	2[illegible].2339	TO	233.9661
GRP02	60	359.5833	1[illegible]5.8641	[illegible]4.9590	143.0000	677.[illegible]	329.6523	TO	389.5139
GRP03	6[illegible]	45[illegible].9331	175.[illegible]773	22.6[illegible]24	173.[illegible]	888.[illegible]	4[illegible]5.7[illegible]58	TO	496.16[illegible]2
TOTAL	18[illegible]	342.5389	158.8805	11.8423	87.0000	888.0000	319.1704	TO	365.9[illegible]72
	FIXED EFFECTS MODEL		126.9374	9.4614			323.8672	TO	361.21[illegible]2
	RANDOM EFFECTS MODEL		117.8447	68.[illegible]376			49.7935	TO	635.2842

TABLE C-24. Multiple Range Test at the Thirty Day Analysis Point for TRIP

```
INTERDICTION OF RESUPPLY IN CZ                                          12/19/77       PAGE   3
FILE    NONAME    (CREATION DATE = 12/19/77)
- - - - - - - - - - - - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - - - - - - - - - - -

      VARIABLE   TOTAL        DEPEN VAR

MULTIPLE RANGE TEST

SCHEFFE PROCEDURE
RANGES FOR THE 0.050 LEVEL -

          3.49   3.49

THE RANGES ABOVE ARE TABLE RANGES.  THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
          69.7583 * RANGE * SQRT(1/N(I) + 1/N(J))

  HOMOGENEOUS SUBSETS    (SUBSETS OF GROUPS, WHOSE HIGHEST AND LOWEST MEANS DO NOT DIFFER BY MORE THAN THE SHORTEST
                          SIGNIFICANT RANGE FOR A SUBSET OF THAT SIZE)

SUBSET  1

GROUP         GRP 1
MEAN        217.1000
- - - - - - - - - - -

SUBSET  2

GROUP         GRP 2
MEAN        359.5833
- - - - - - - - - - -

SUBSET  3

GROUP         GRP 3
MEAN        450.9331
- - - - - - - - - - -
```

APPENDIX D

SAMPLE OUTPUT FROM THE MEAN VALUE DIFFERENTIAL ANALYSIS (MVDA) PROGRAM

A typical portion of the computer output from the MVDA program is presented in this appendix. The numerical designator of each level is consistent with the description in Appendix B. The sub-mean column refers to the mean of the MOE for any parametric case.

ANALYSIS OF ORDERED FACTORS-- BUSH REPL INUM TRIP BLNK

GRAND MEAN = 342.539

MAIN EFFECT FACTOR-- BUSH

LEVEL	DIFFERENTIAL FROM GRAND MEAN	SUB-MEAN
1	50.428	392.967
2	-50.428	292.111

SECOND ORDER TERMS-- BUSH REPL

LEVEL (FACTOR 1)	LEVEL (FACTOR 2)	DIFFERENTIAL FROM GRAND MEAN	SUB-MEAN
1	1	91.172	433.711
1	2	9.683	352.222
2	1	1.550	344.089
2	2	-102.405	240.133

THIRD ORDER TERMS-- BUSH REPL NUM

LEVEL (FACTOR 1)	LEVEL (FACTOR 2)	LEVEL (FACTOR 3)	DIFFERENTIAL FROM GRAND MEAN	SUB-MEAN
1	1	1	213.261	555.800
1	1	2	72.061	414.600
1	1	3	-11.806	330.733
1	2	1	75.261	417.800
1	2	2	40.061	382.600
1	2	3	-86.272	256.267
2	1	1	104.528	447.067
2	1	2	-14.139	328.400
2	1	3	-85.739	256.800
2	2	1	-34.406	308.133
2	2	2	-111.139	231.400
2	2	3	-161.672	180.867

FOURTH ORDER TERMS-- BUSH REPL 'NUM TRIP

LEVEL (FACTOR 1)	LEVEL (FACTOR 2)	LEVEL (FACTOR 3)	LEVEL (FACTOR 4)	DIFFERENTIAL FROM GRAND MEAN	SUB-MEAN
1	1	1	1	-18.339	324.200
1	1	1	2	237.461	580.000
1	1	1	3	420.661	763.200
1	1	2	1	-37.939	254.600
1	1	2	2	49.461	392.000
1	1	2	3	254.661	597.200
1	1	3	1	-143.939	198.600
1	1	3	2	-12.539	330.000
1	1	3	3	121.061	463.600
1	2	1	1	-77.339	265.200
1	2	1	2	72.861	415.400
1	2	1	3	230.261	572.800
1	2	2	1	-125.939	216.600
1	2	2	2	55.861	398.400
1	2	2	3	190.261	532.800
1	2	3	1	-196.739	145.800
1	2	3	2	-61.339	281.200
1	2	3	3	-0.739	341.800
2	1	1	1	-74.939	267.600
2	1	1	2	131.261	473.800
2	1	1	3	257.261	599.800
2	1	2	1	-115.339	227.200
2	1	2	2	3.461	346.000
2	1	2	3	69.461	412.000
2	1	3	1	-157.539	185.000
2	1	3	2	-56.139	286.400
2	1	3	3	-43.539	299.000
2	2	1	1	-109.739	232.800
2	2	1	2	-1.939	340.600
2	2	1	3	8.461	351.000
2	2	2	1	-167.139	175.400
2	2	2	2	-71.539	271.000
2	2	2	3	-94.739	247.800
2	2	3	1	-230.339	112.200
2	2	3	2	-142.339	200.200
2	2	3	3	-112.339	230.200

APPENDIX E

GRAPHS

This appendix displays the output of the Mean Value Differential Analysis program in graphic format. The graphs are grouped such that only two factors are variable on any one graph while the other two factors are variable within a set of graphs as follows:

FIGURES	FACTORS VARIABLE ON EACH GRAPH	FACTORS VARIABLE IN THE SET
1-6	Number of Trips per Day Replacement Time	Ambush Probability Maximum Number of Vehicles Available per Trip
7-12	Maximum Number of Vehicles Available per Trip Replacement Time	Ambush Probability Number of Trips per Day
13-16	Number of Trips per Day Maximum Number of Vehicles Available per Trip	Replacement Time Ambush Probability
17-22	Maximum Number of Vehicles Available per Trip Ambush Probability	Replacement Time Number of Trips
23-28	Ambush Probability Number of Trips	Replacement Time Maximum Number of Vehicles Available per Trip

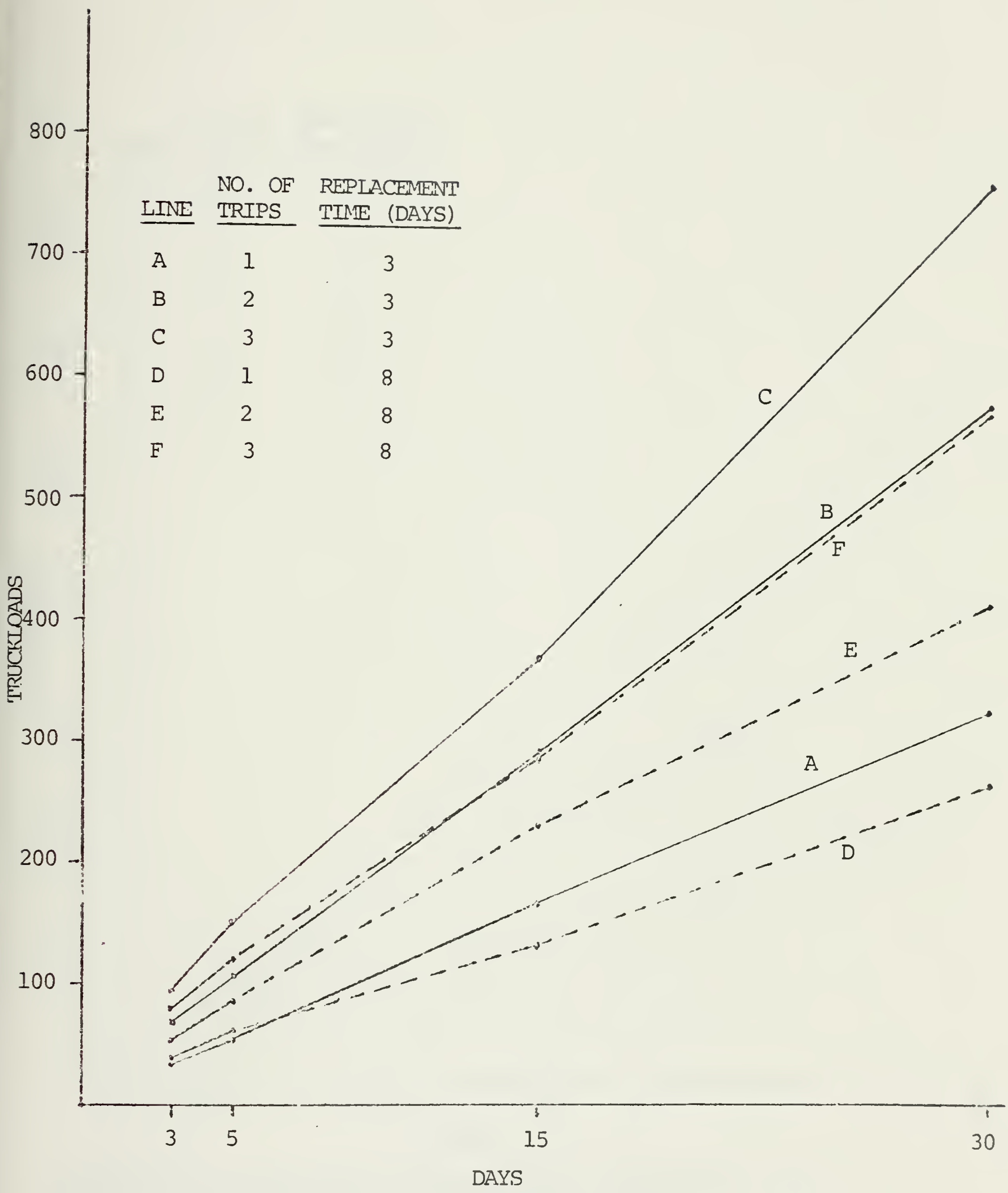


FIGURE 1. Truckloads Delivered for P(ambush) = 0.1, Max. Vehicles Available = 15

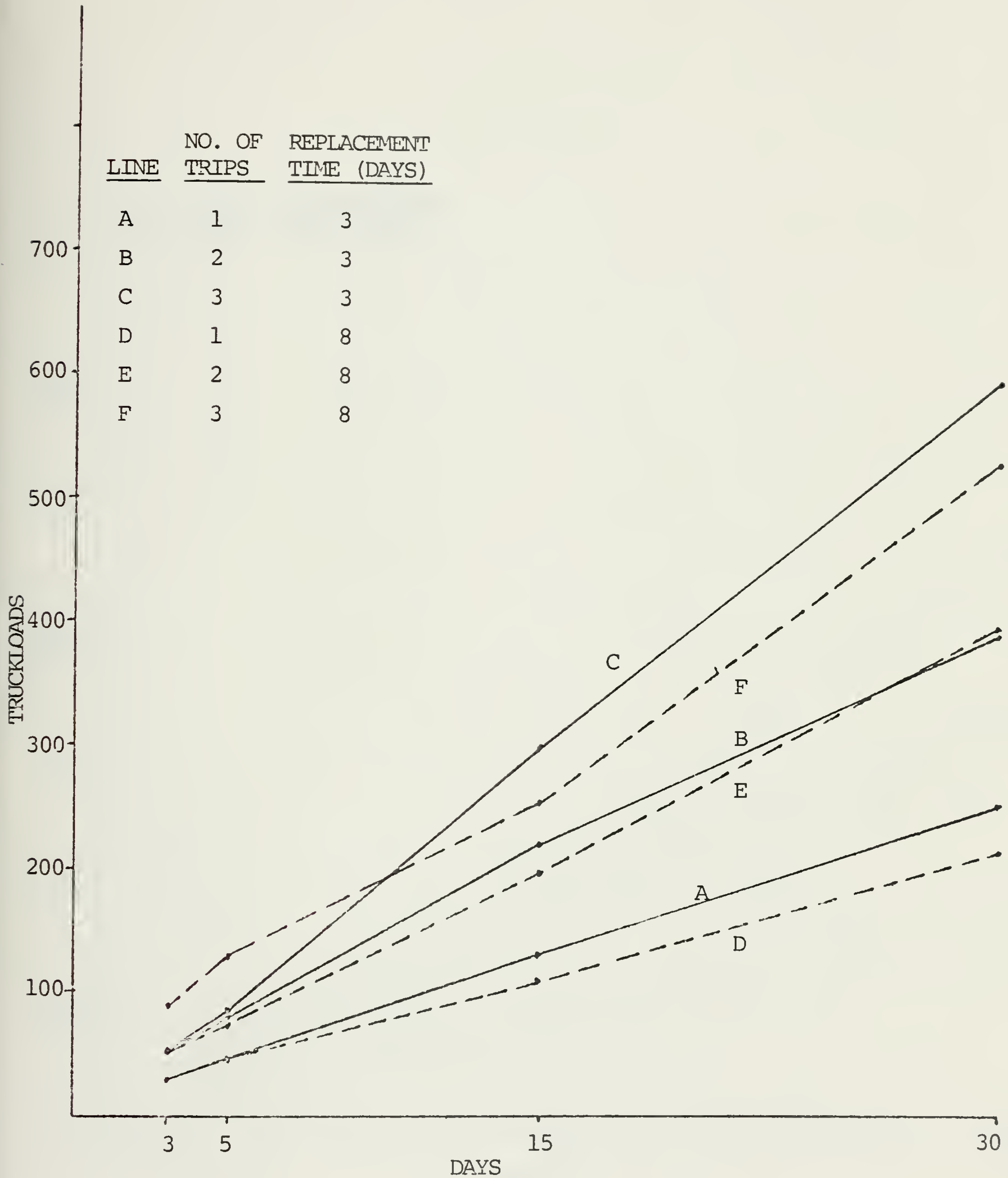


FIGURE 2. Truckloads Delivered for P(ambush) = 0.1, Max. Vehicles Available = 12

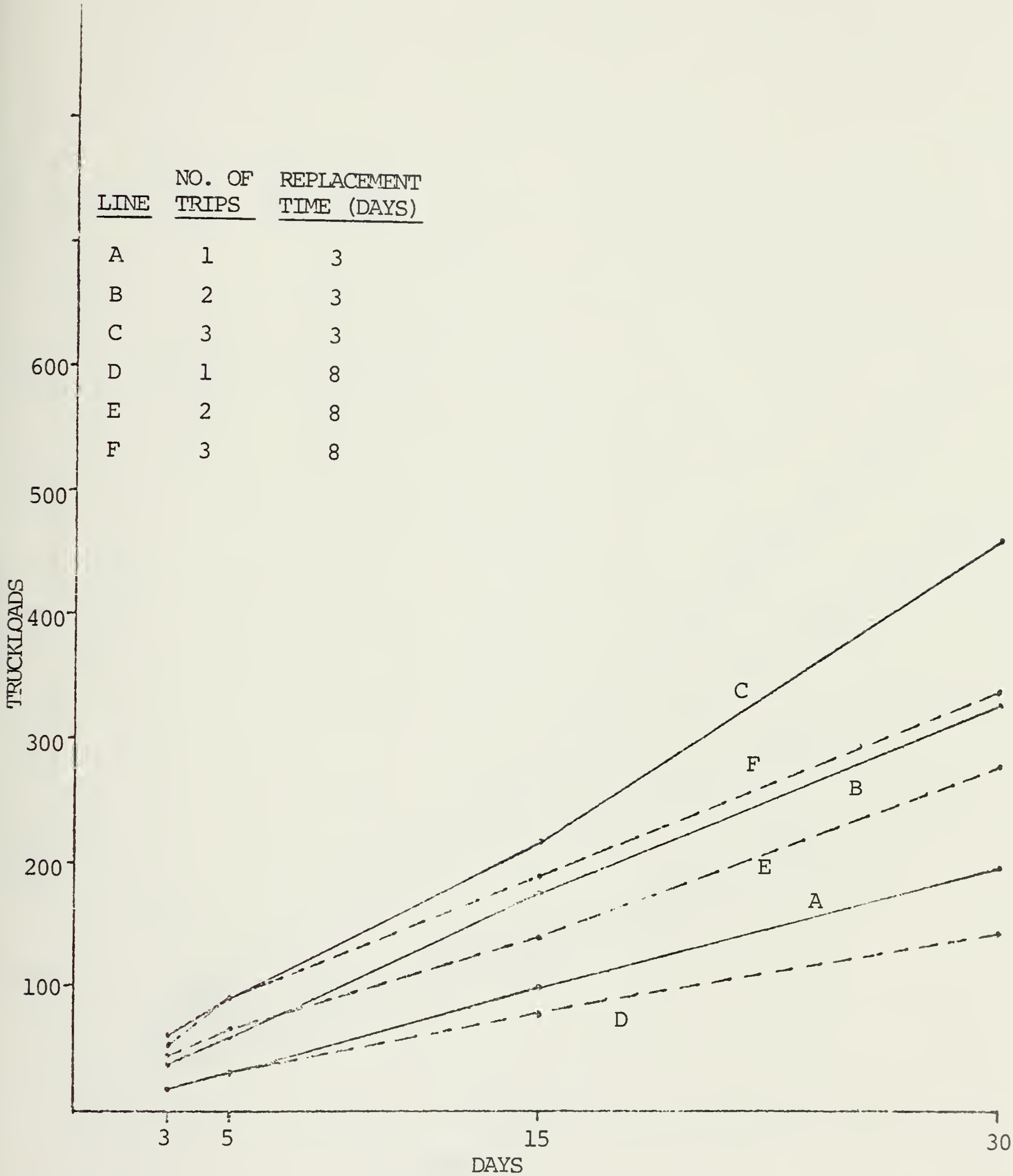


FIGURE 3. Truckloads Delivered for P(ambush) = 0.1,
Max. Vehicles Available = 9

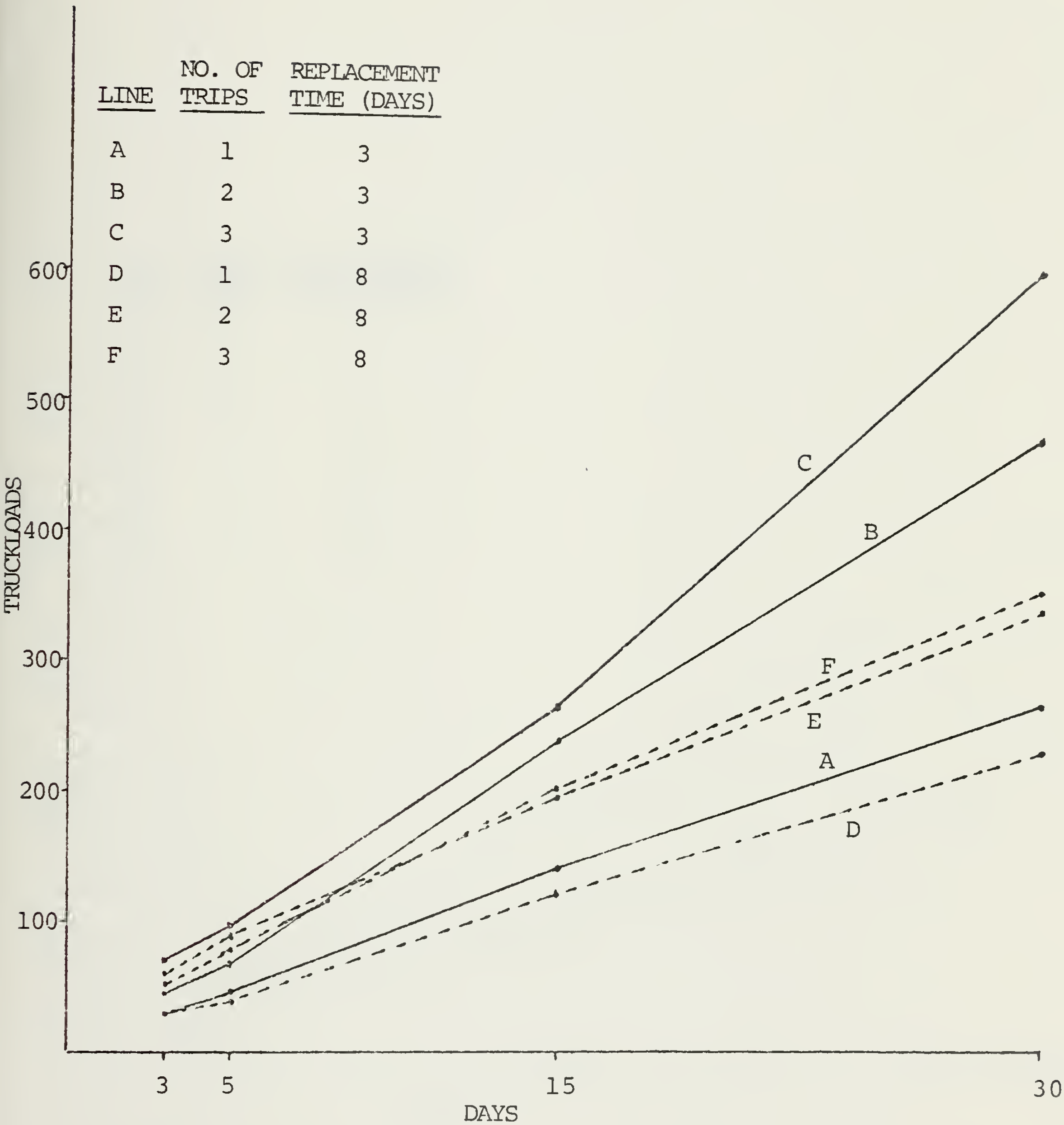


FIGURE 4. Truckloads Delivered for P(ambush) = 0.2,
Max. Vehicles Available = 15

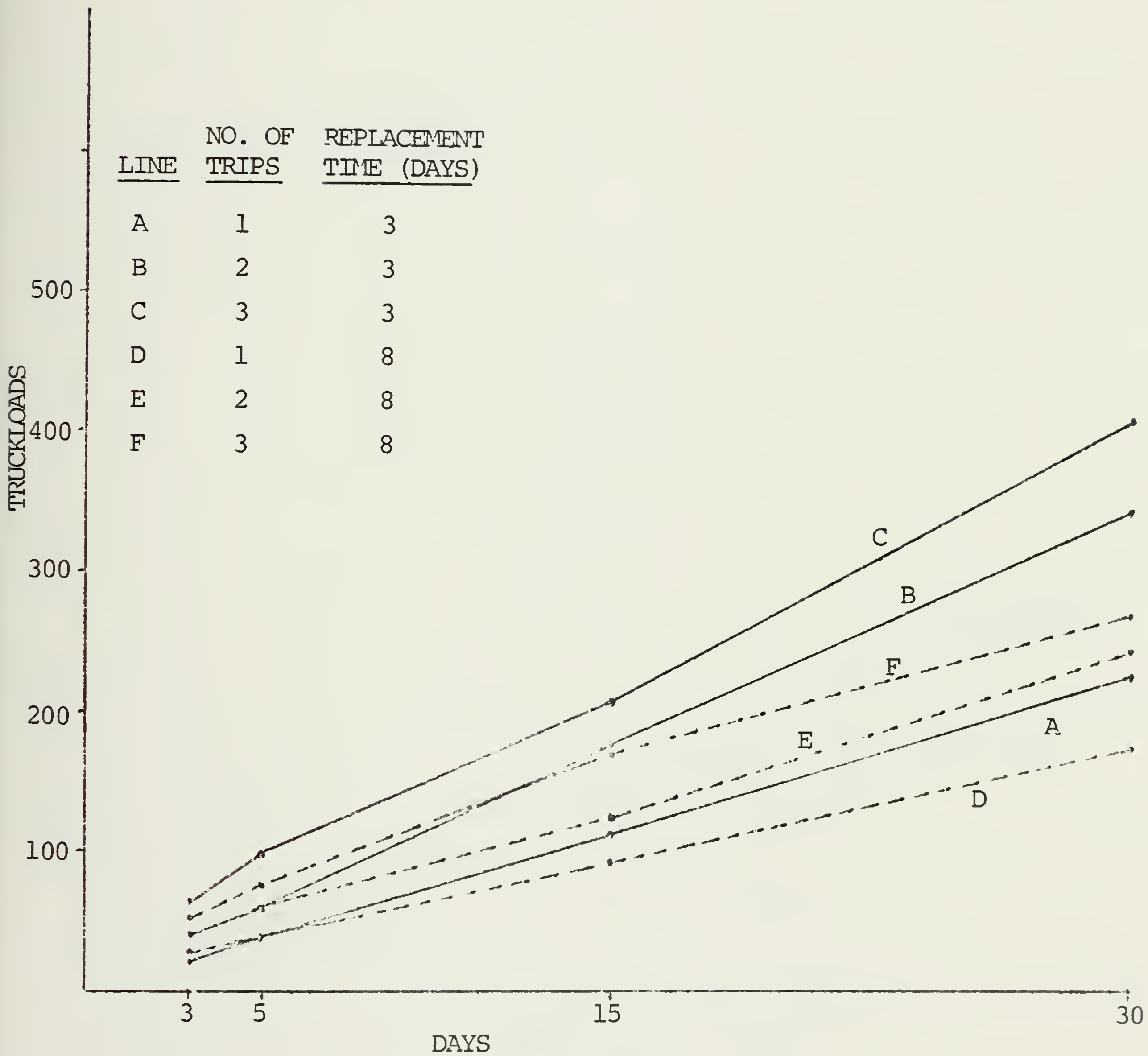


FIGURE 5. Truckloads Delivered for P(ambush) = 0.2, Max. Vehicles Available = 12

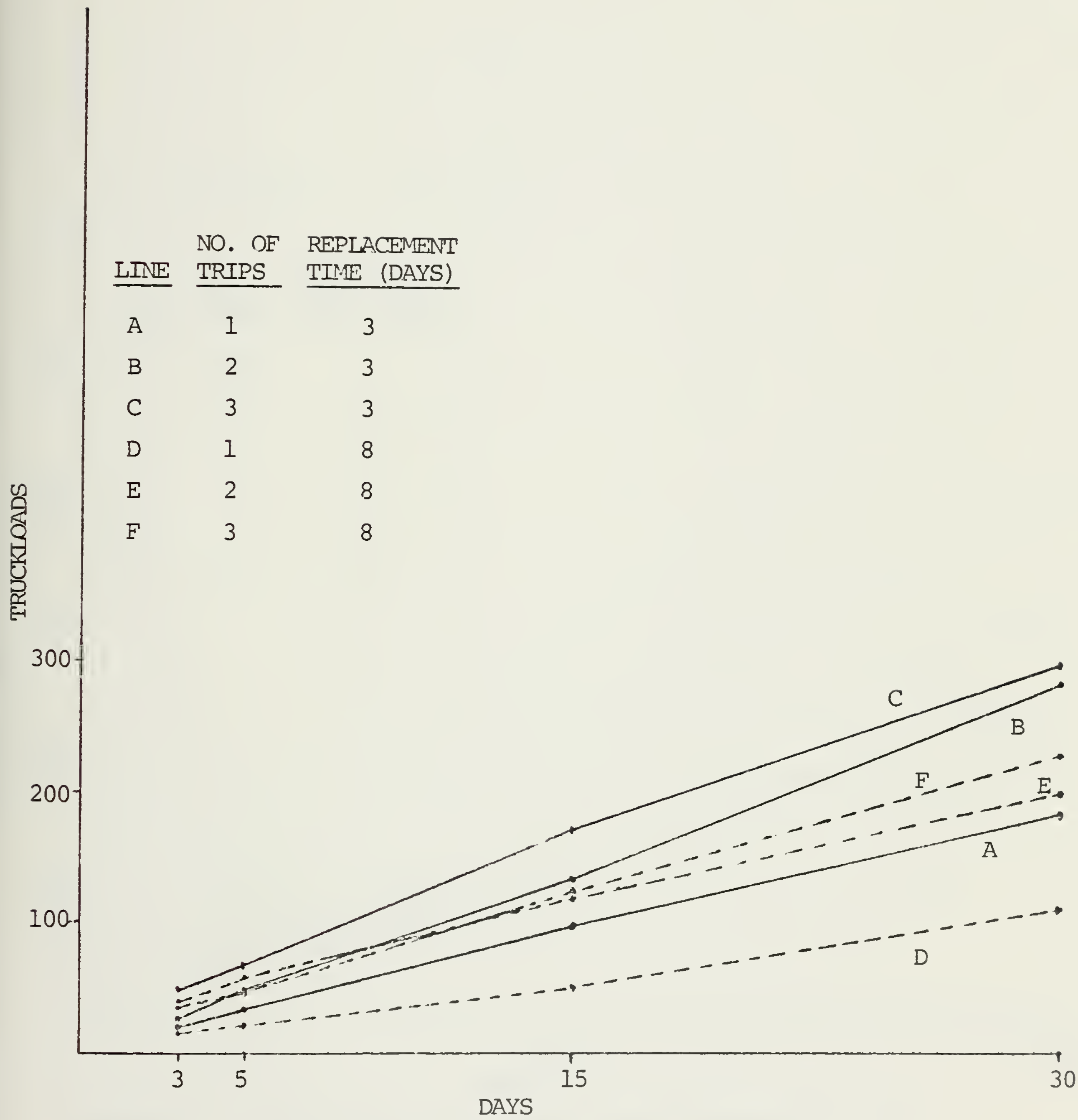


FIGURE 6. Truckloads Delivered for P(ambush) = 0.2,
Max. Vehicles Available = 9

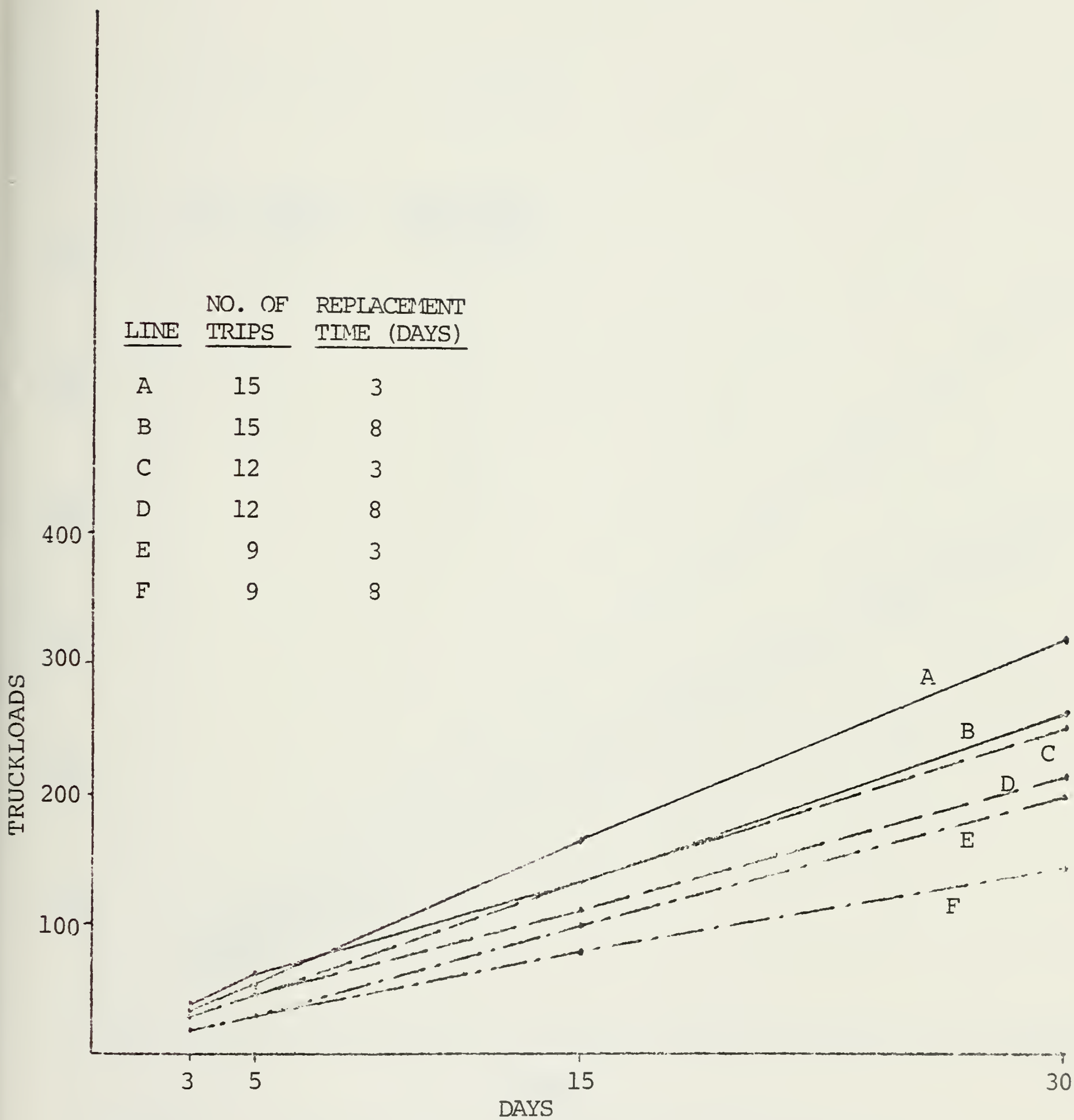


FIGURE 7. Truckloads Delivered for P(ambush) = 0.1, No. of Trips = 1

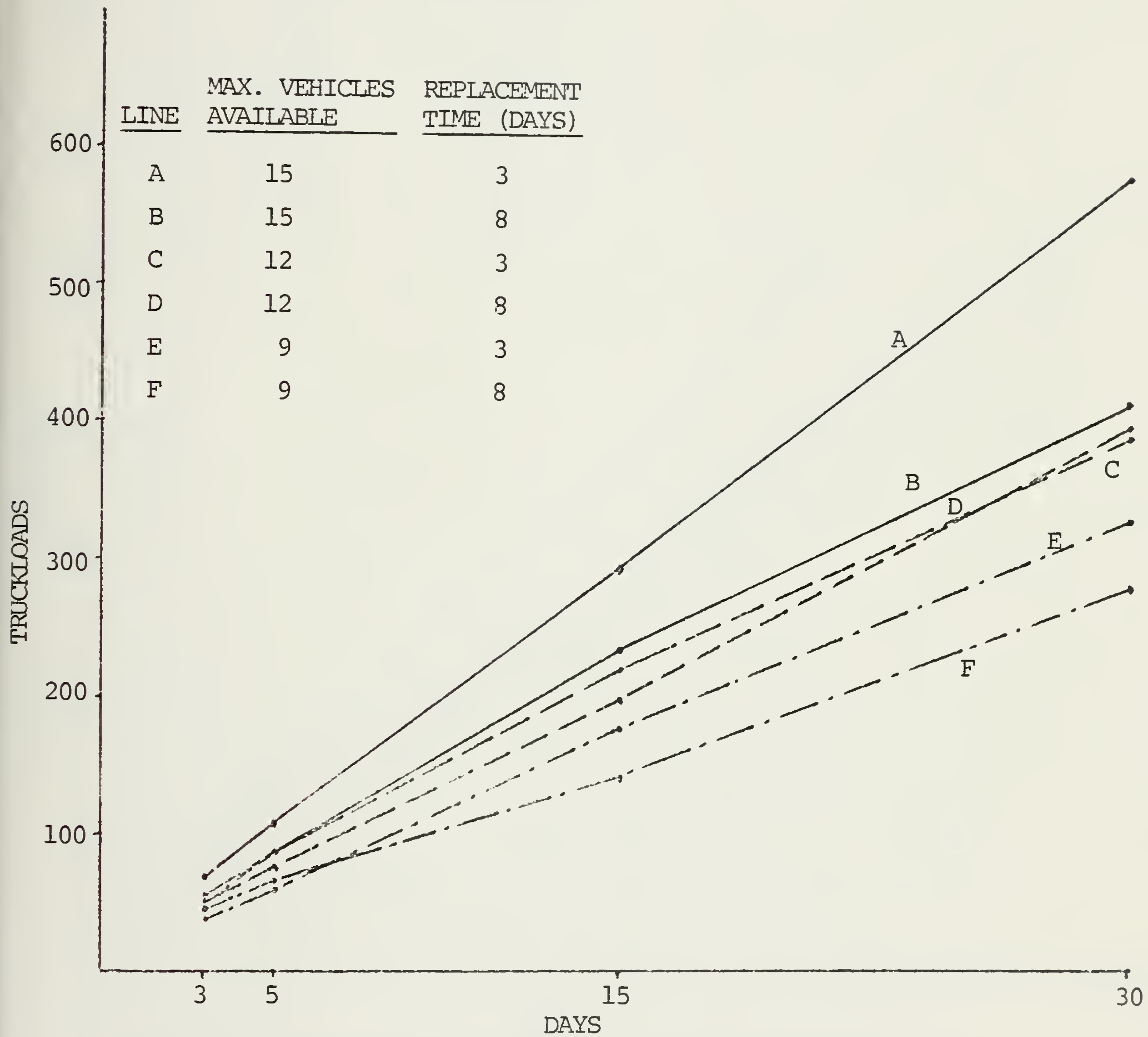
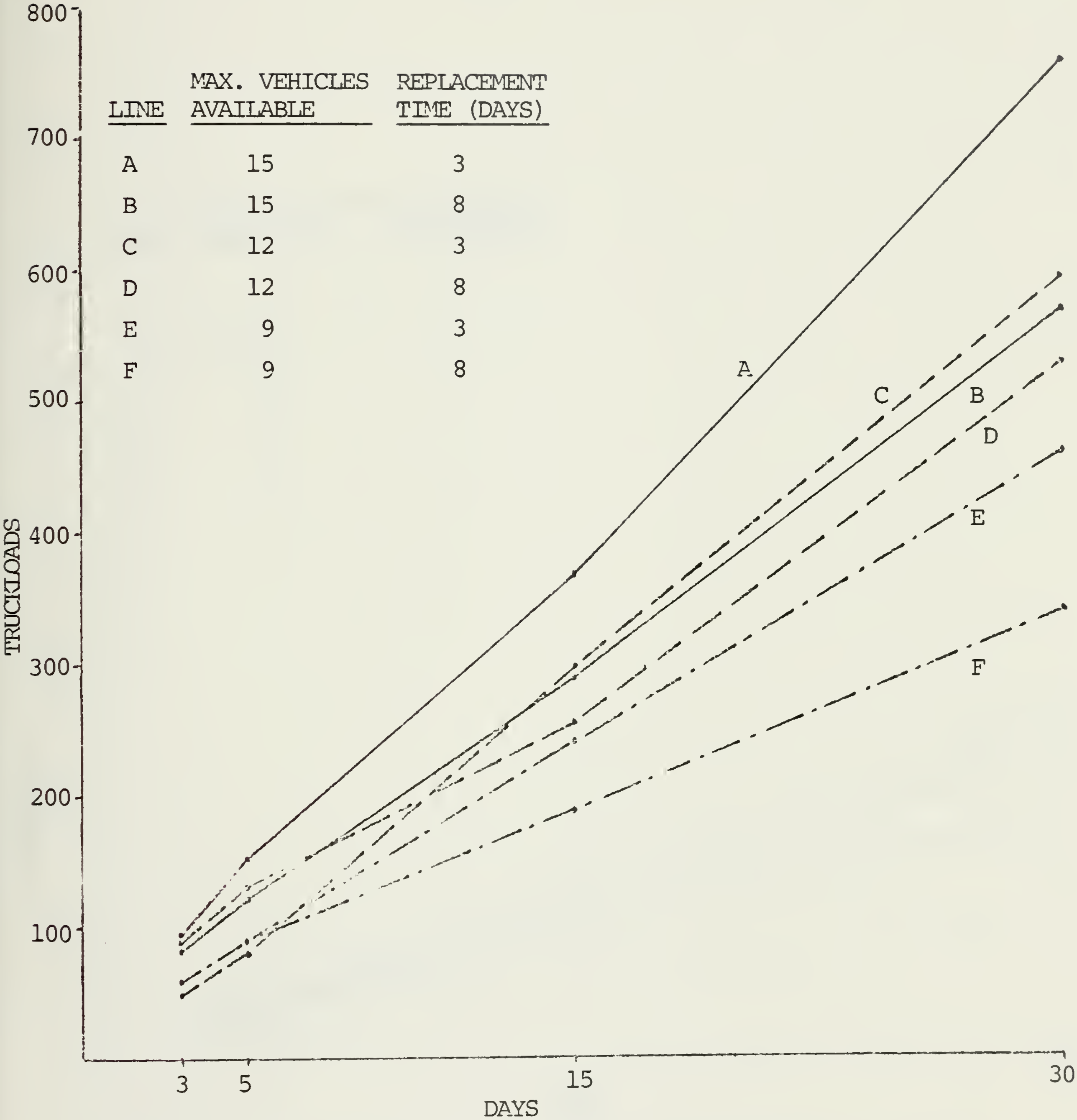


FIGURE 8. Truckloads Delivered for P(ambush) = 0.1,
No. of Trips = 2



LINE	MAX. VEHICLES AVAILABLE	REPLACEMENT TIME (DAYS)
A	15	3
B	15	8
C	12	3
D	12	8
E	9	3
F	9	8

FIGURE 9. Truckloads Delivered for P(ambush) = 0.1, No. of Trips = 3

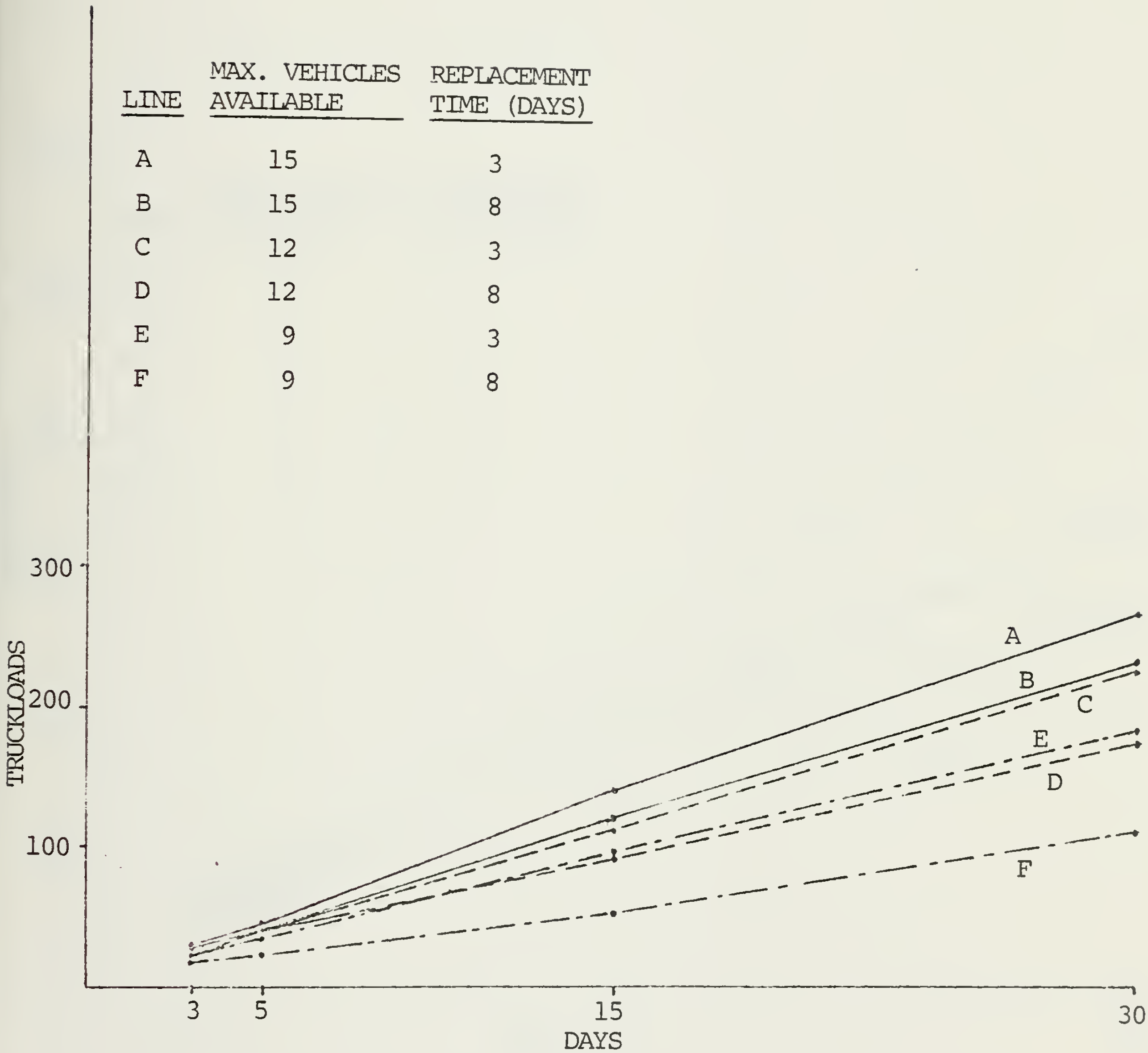


FIGURE 10. Truckloads Delivered for P(ambush) = 0.2,
No. of Trips = 1

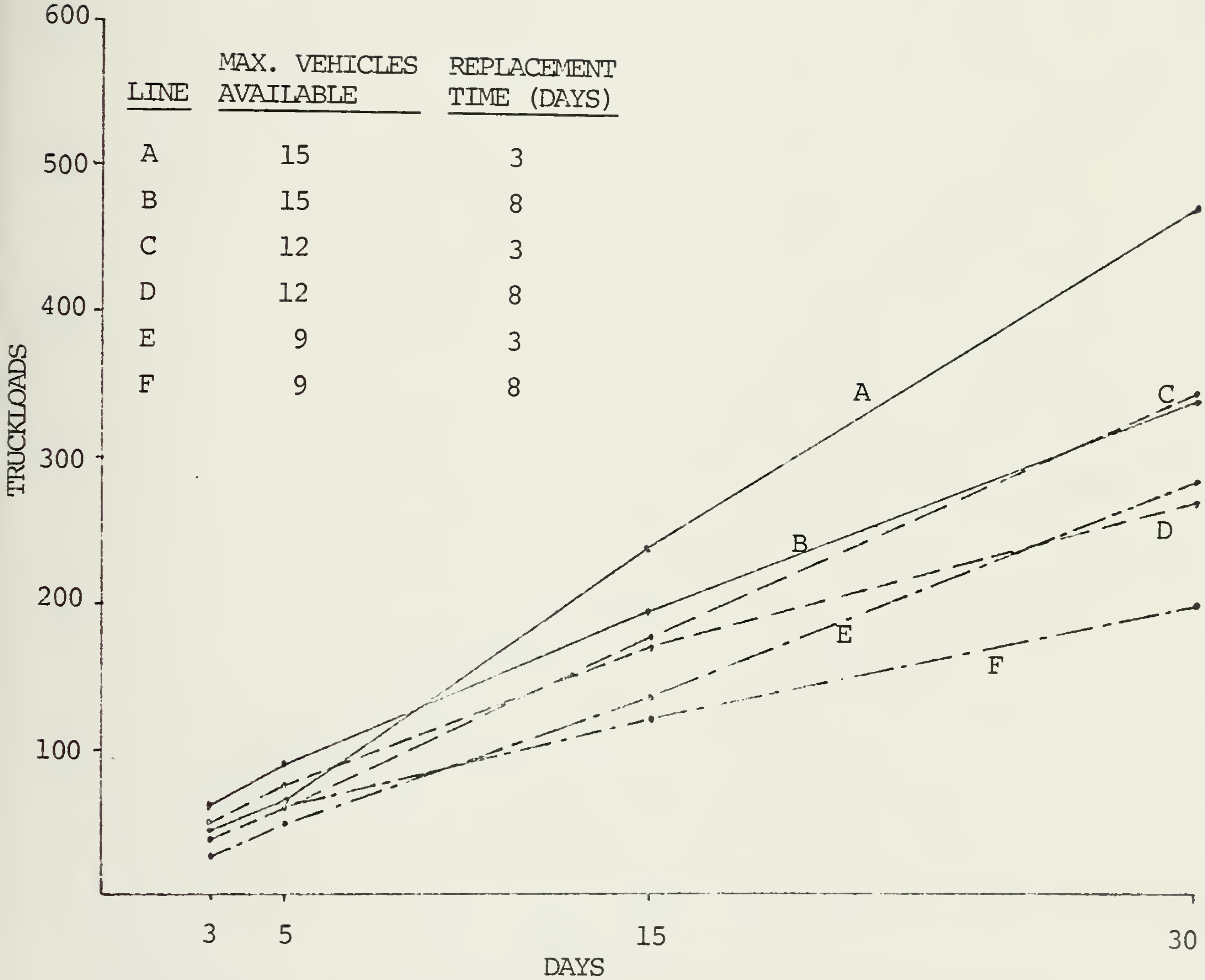


FIGURE 11. Truckloads Delivered for P(ambush) = 0.2, No. of Trips = 2

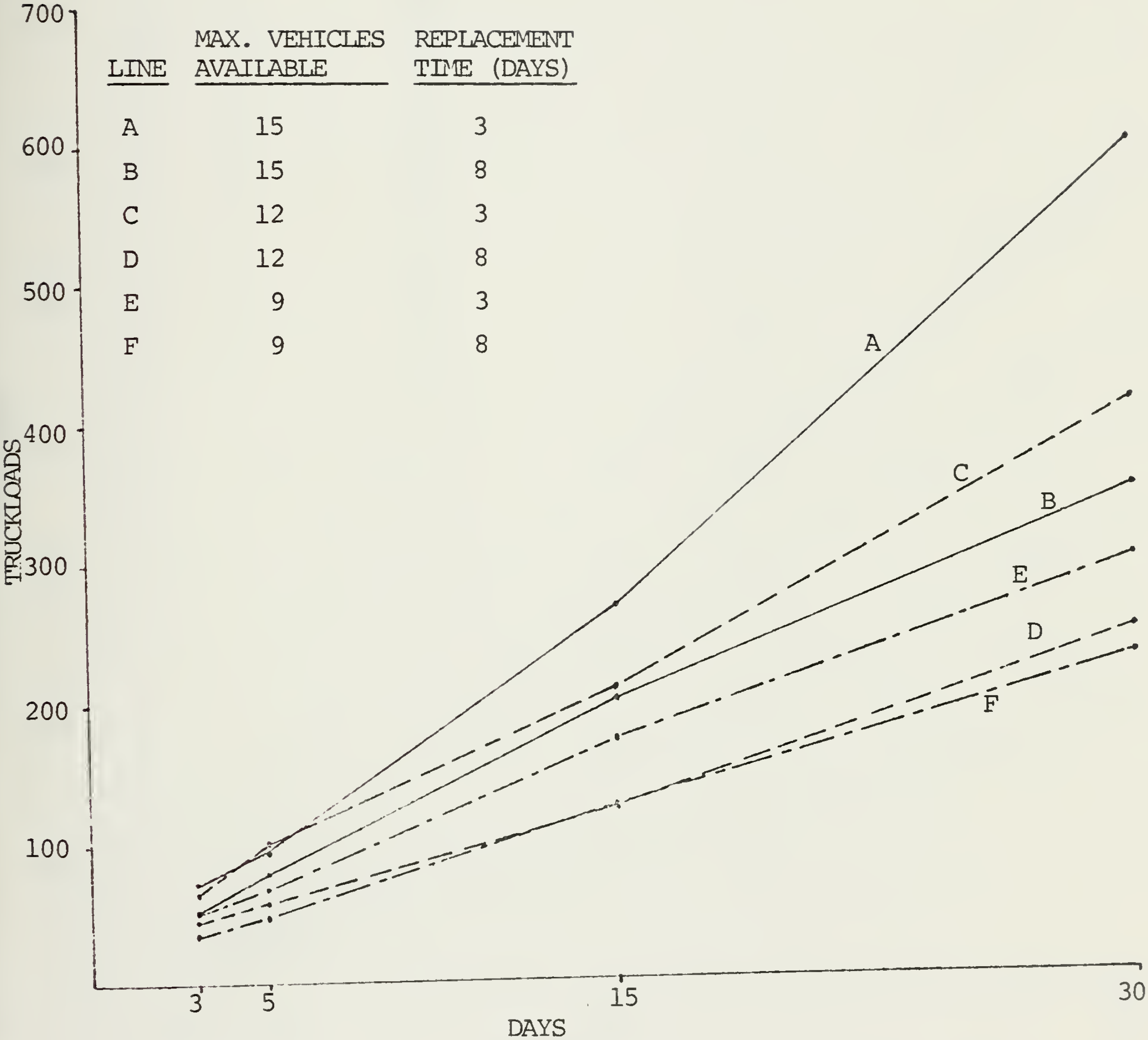


FIGURE 12. Truckloads Delivered for P(ambush) = 0.2, No. of Trips = 3

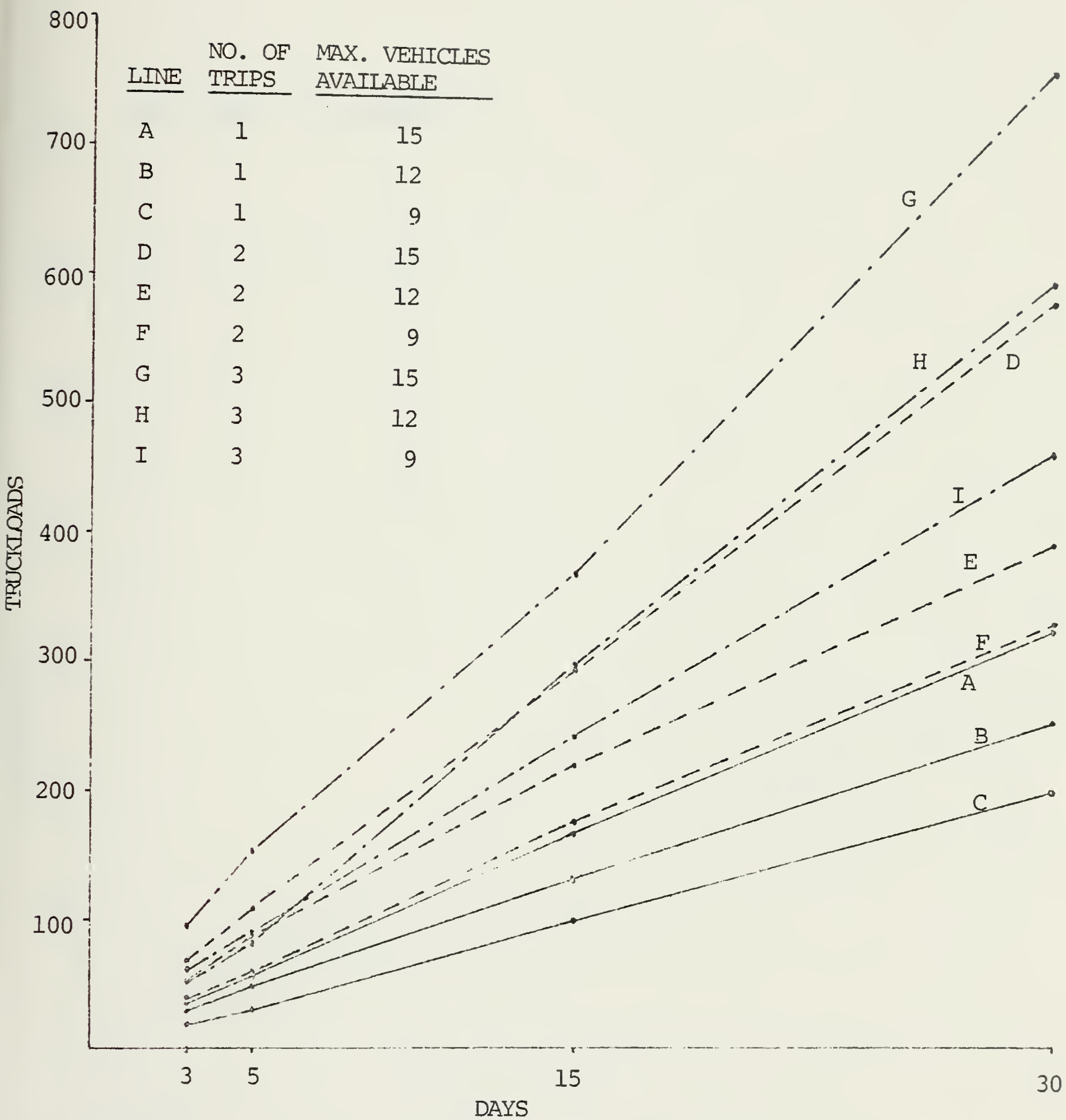


FIGURE 13. Truckloads Delivered for Replacement Time = 3 Days, P(ambush) = 0.1

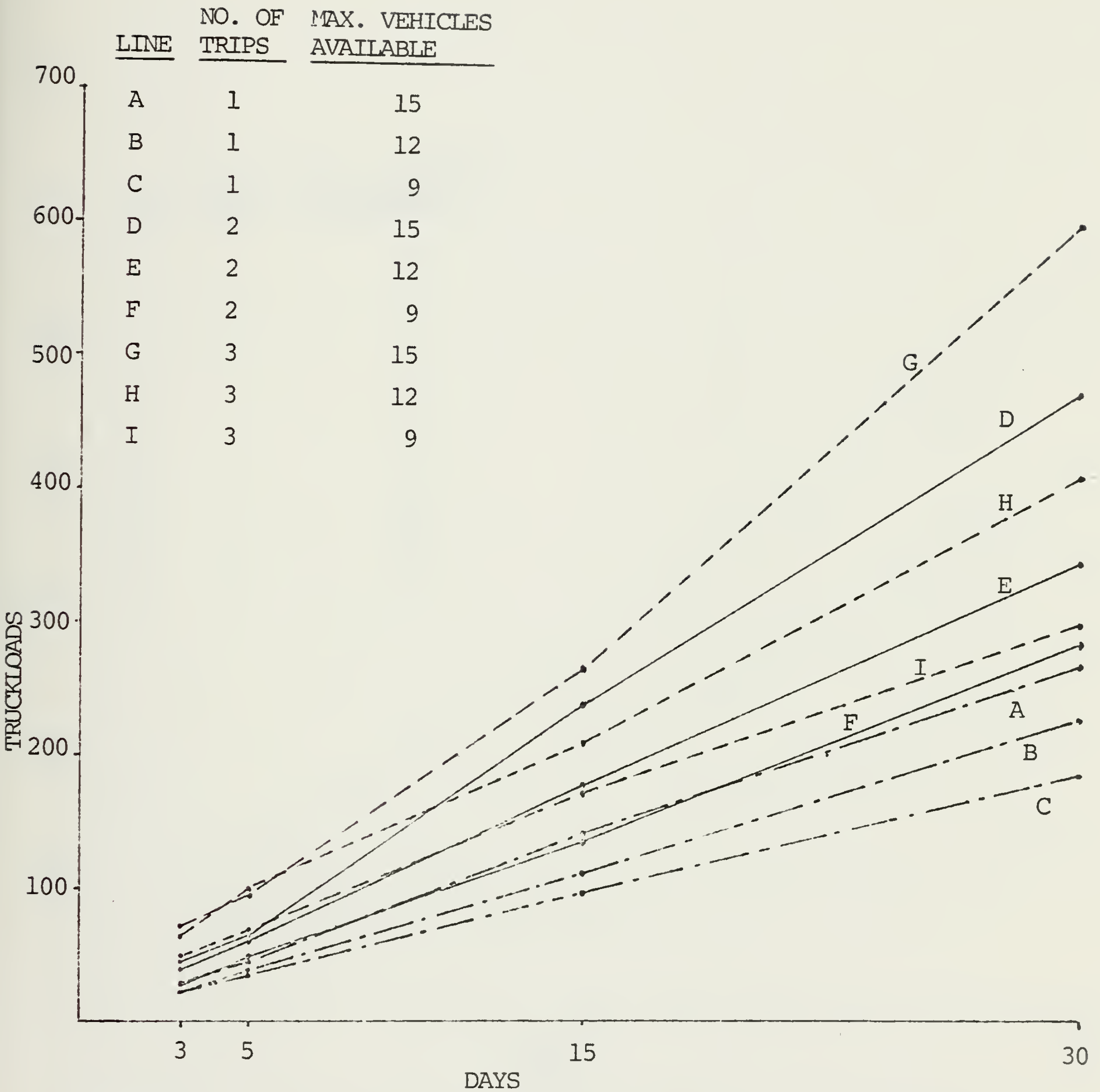


FIGURE 14. Truckloads Delivered for Replacement Time = 3 Days, P(ambush) = 0.2

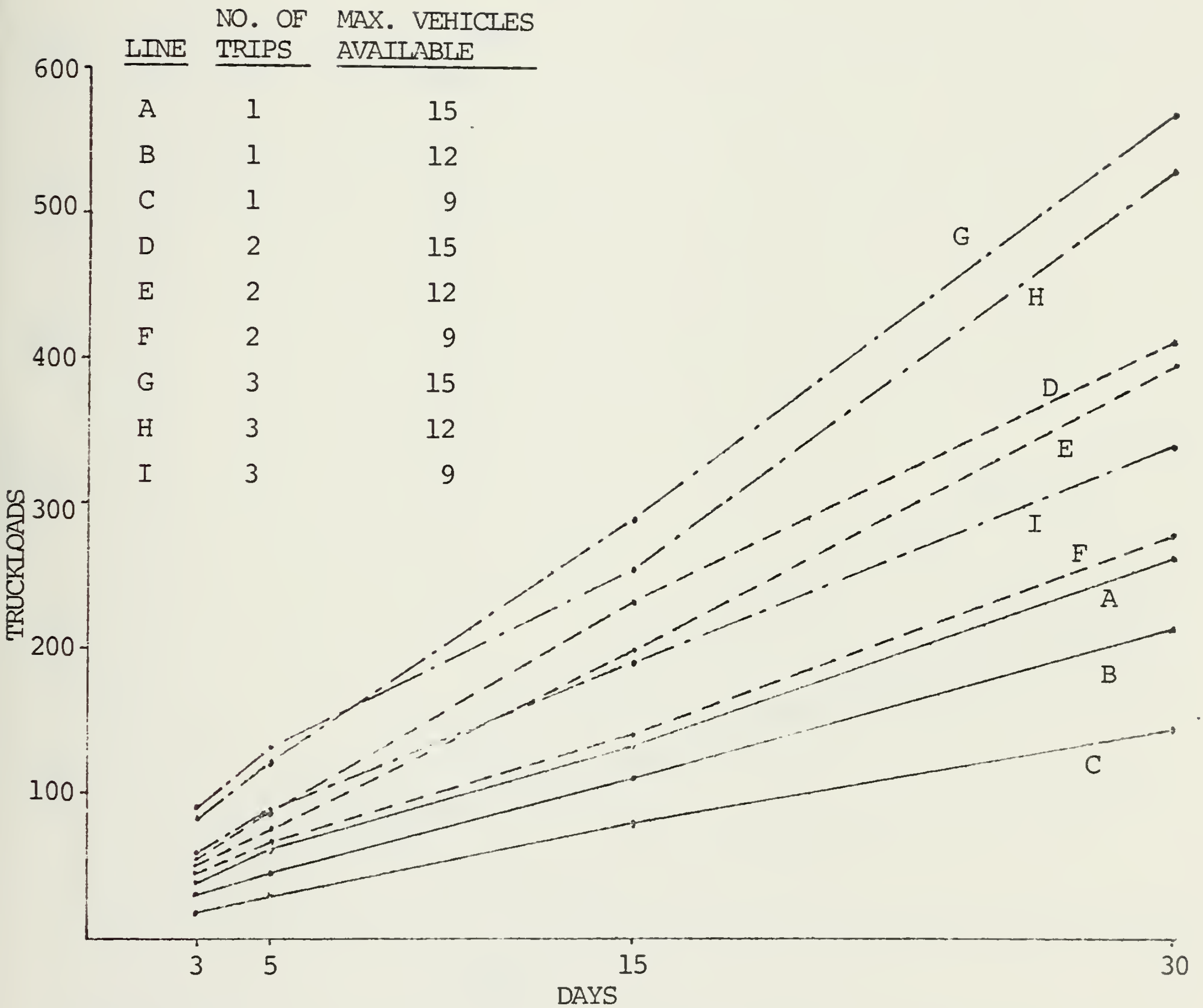


FIGURE 15. Truckloads Delivered for Replacement Time = 8 Days, P(ambush) = 0.1

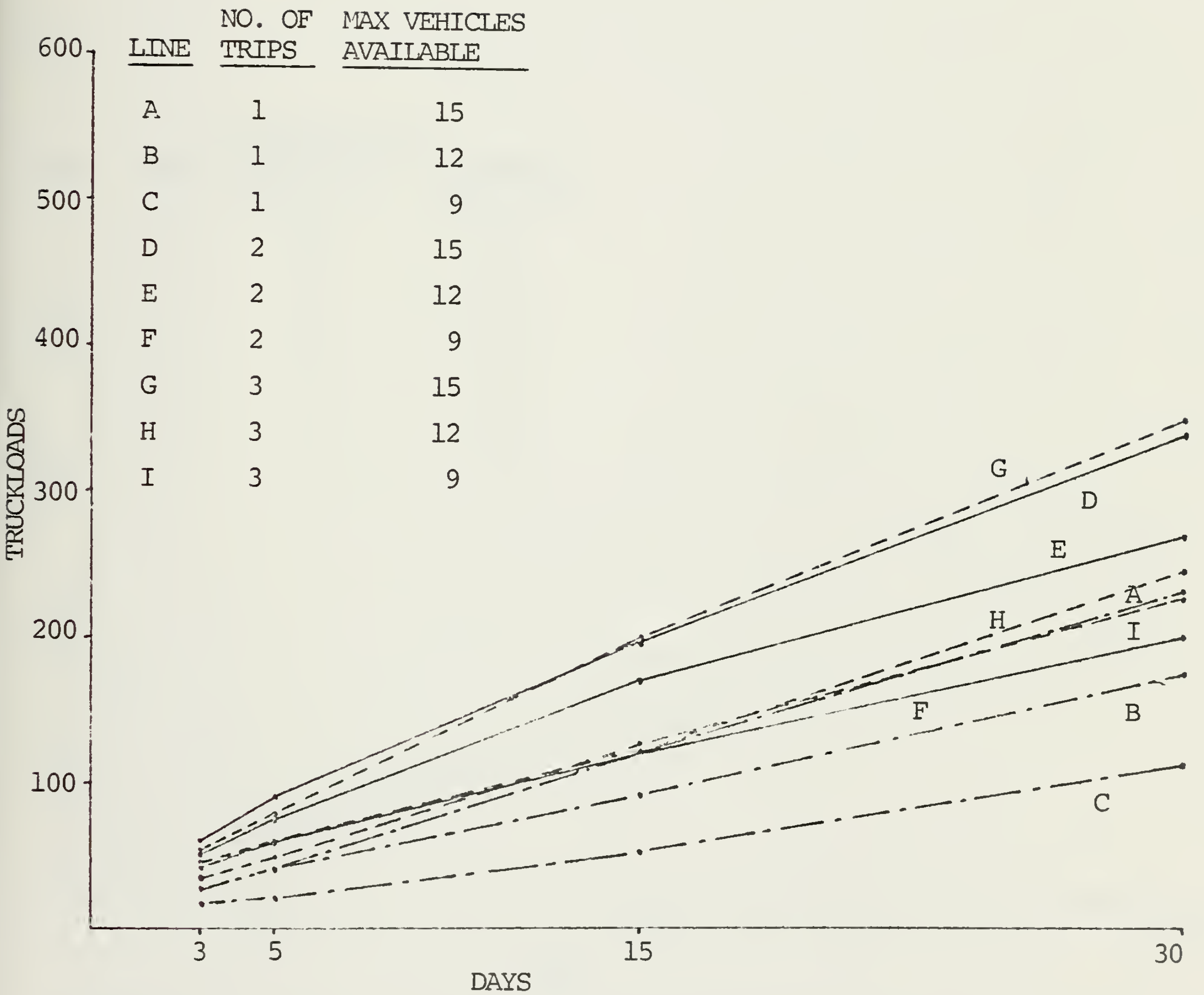


FIGURE 16. Truckloads Delivered for Replacement Time = 8 Days, P(ambush) = 0.2

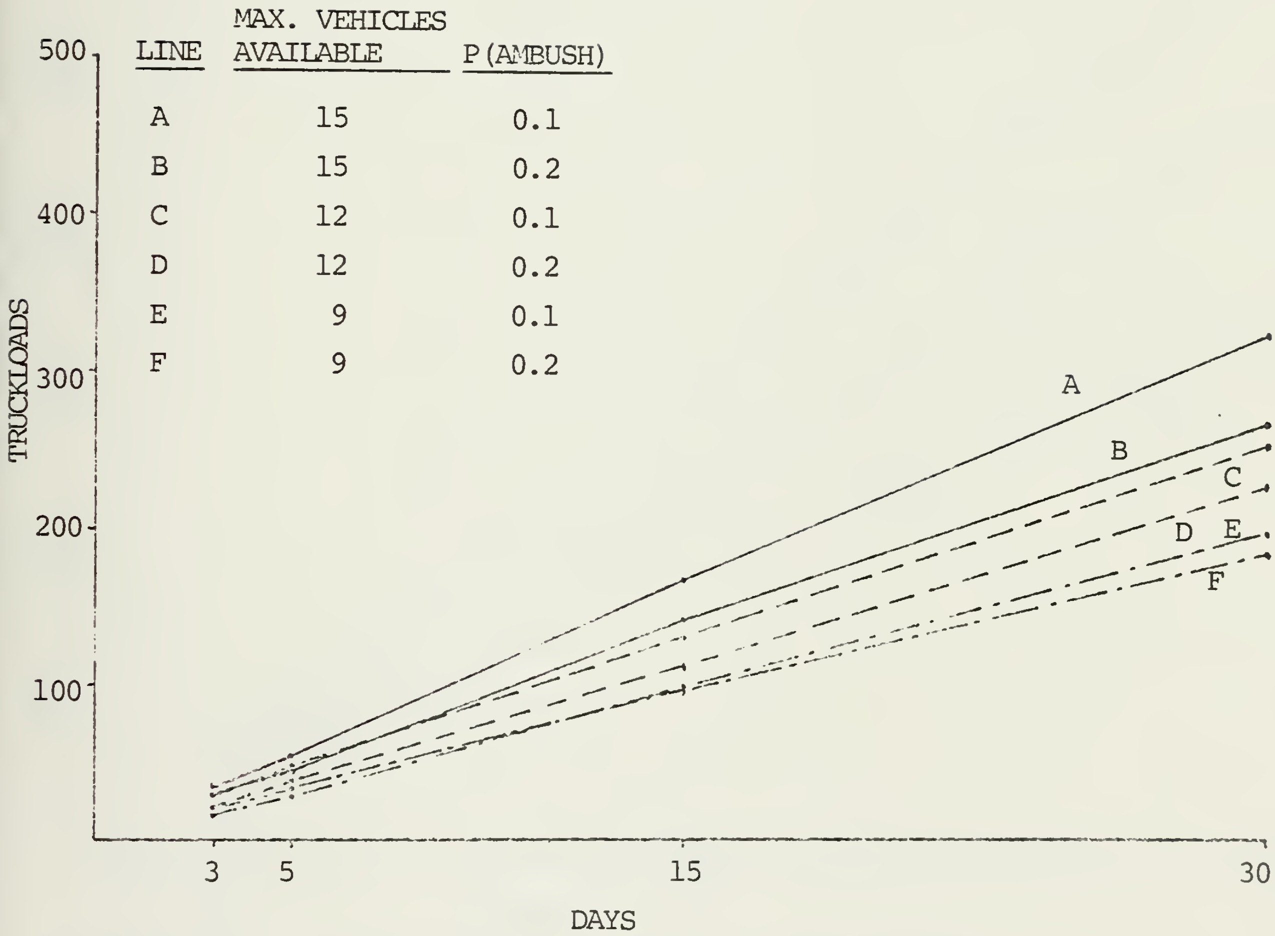


FIGURE 17. Truckloads Delivered for Replacement Time = 3, No. of Trips = 1

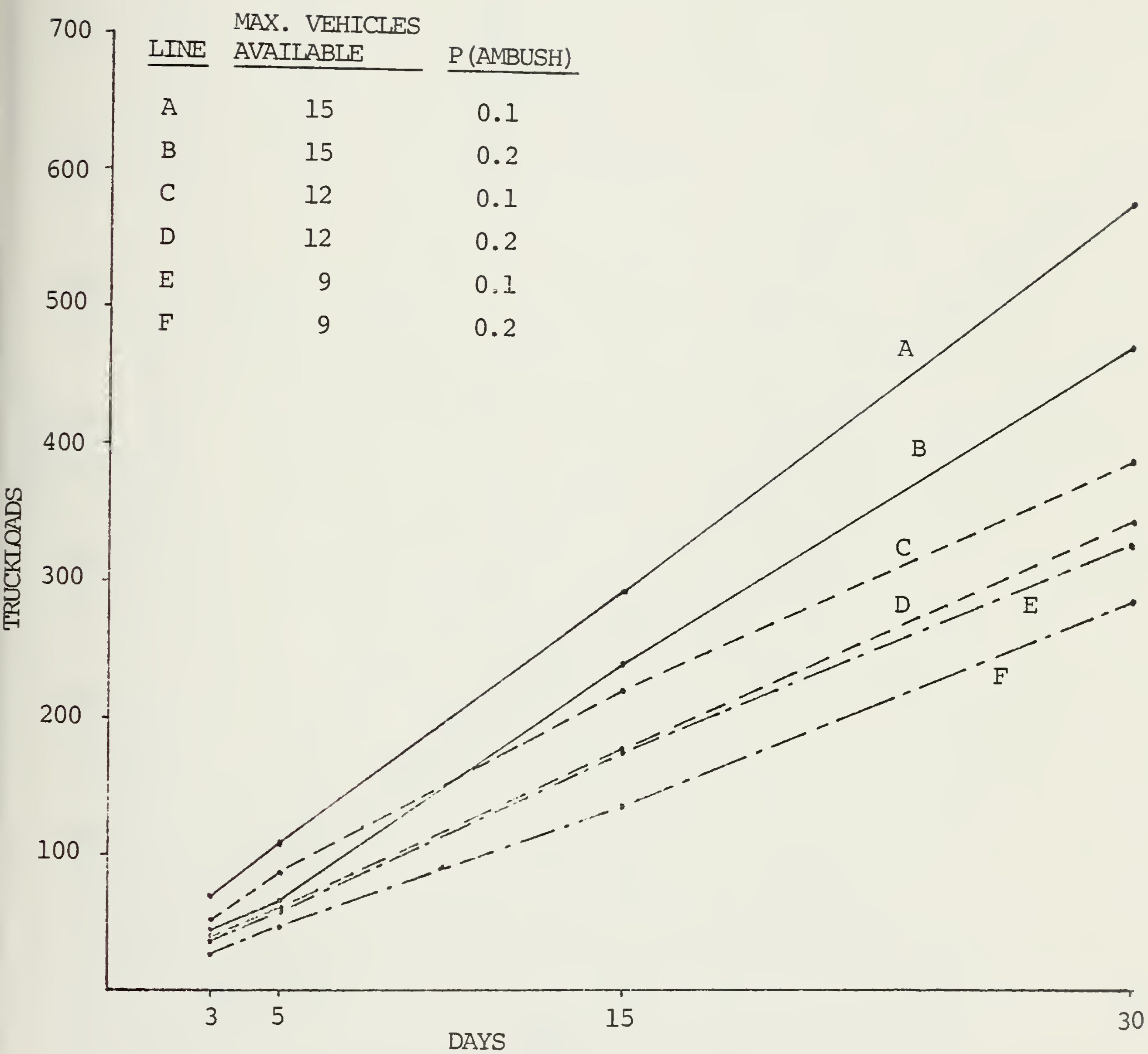


FIGURE 18. Truckloads Delivered for Replacement Time = 3, No. of Trips = 2

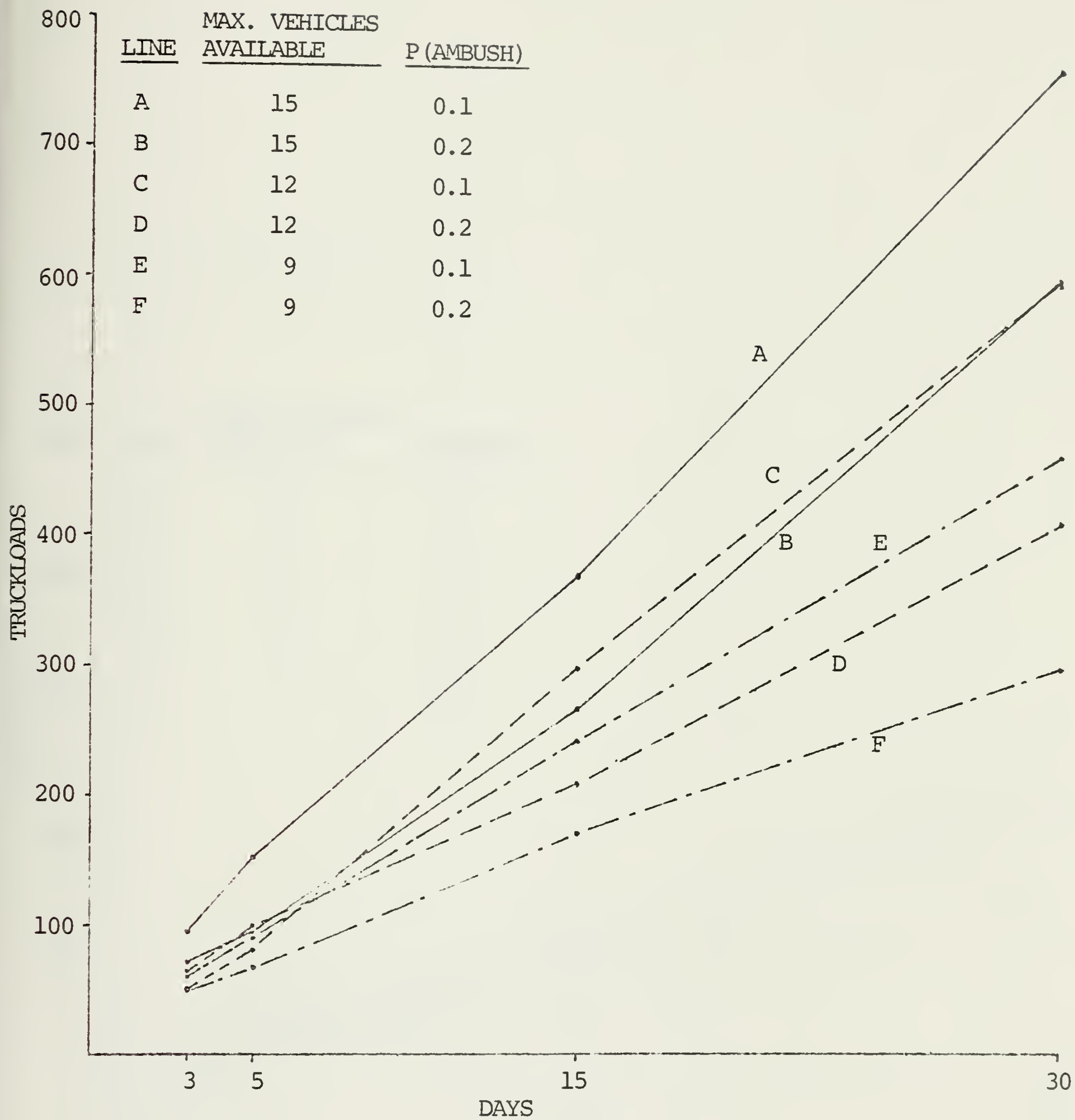


FIGURE 19. Truckloads Delivered for Replacement Time = 3, No. of Trips = 3

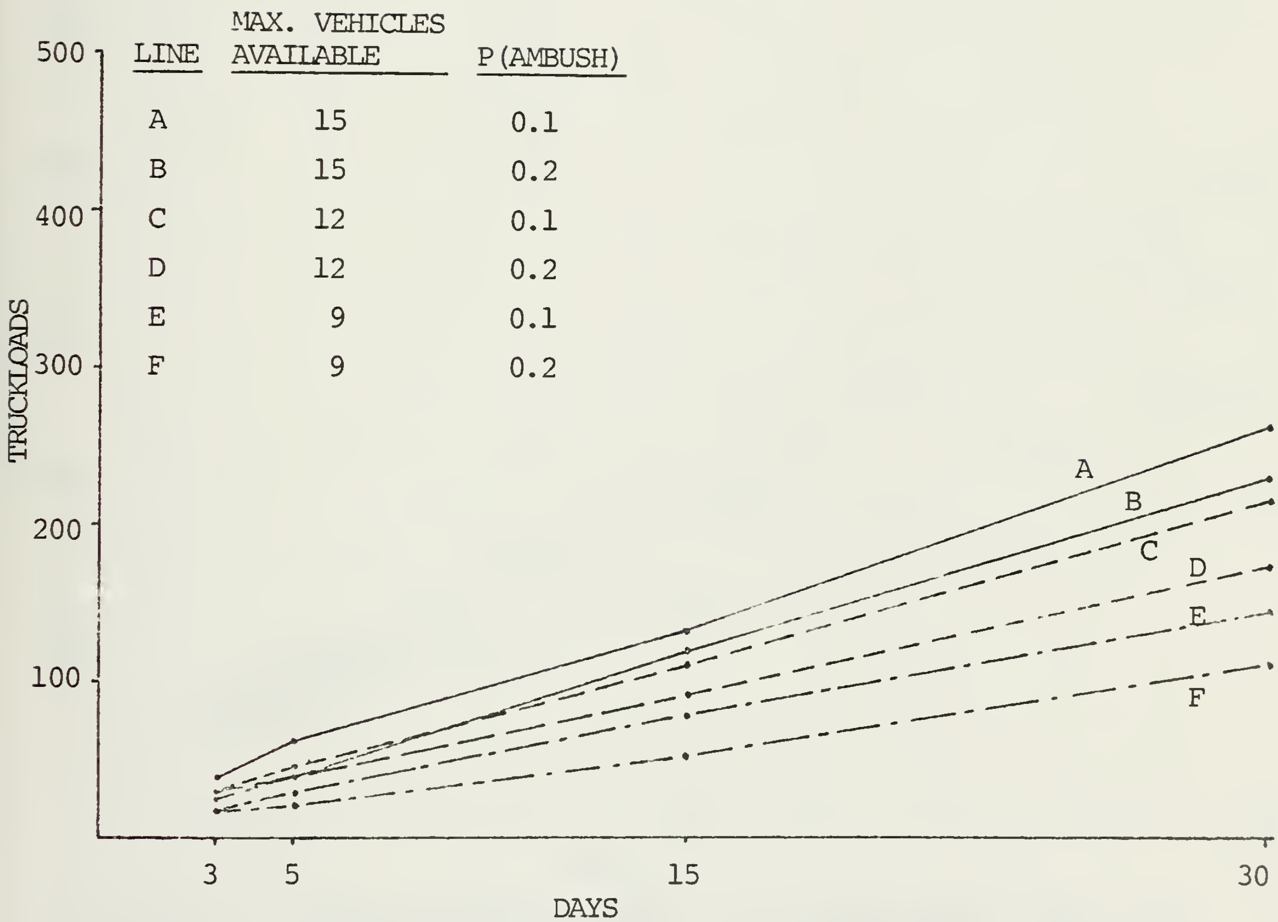


FIGURE 20. Truckloads Delivered for Replacement Time = 8, No. of Trips = 1

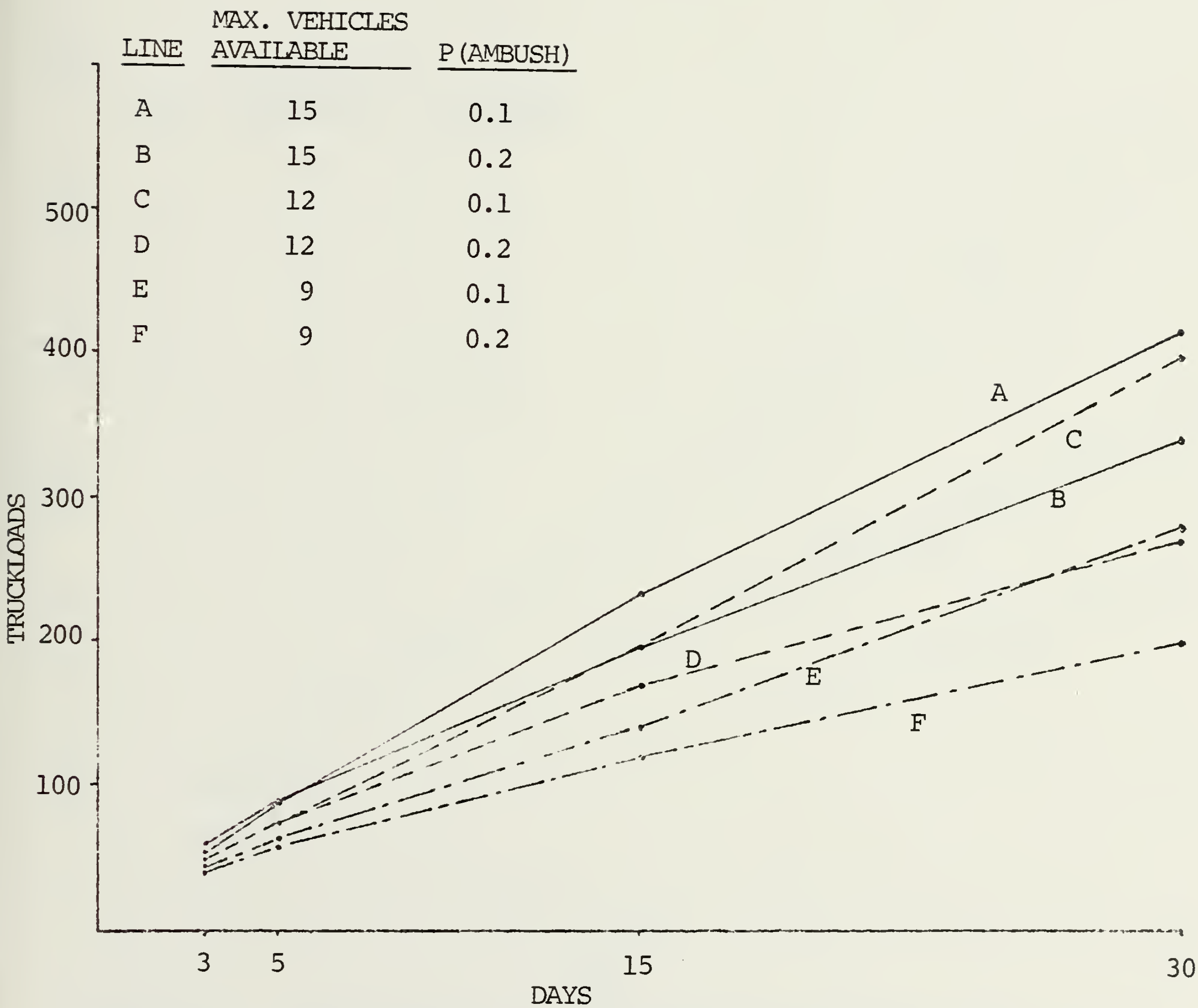


FIGURE 21. Truckloads Delivered for Replacement Time = 8,
No. of Trips = 2

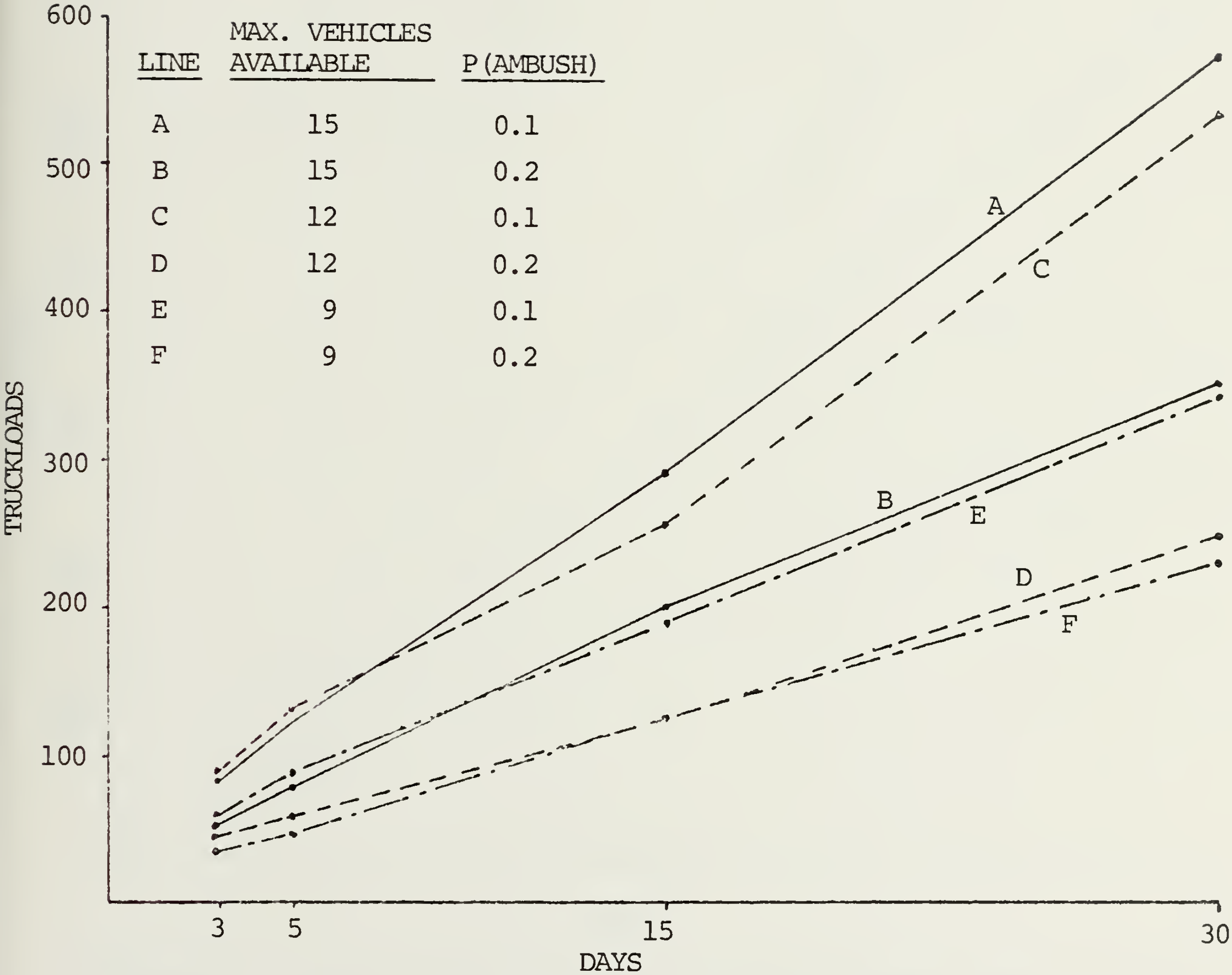


FIGURE 22. Truckloads Delivered for Replacement Time = 8, No. of Trips = 3

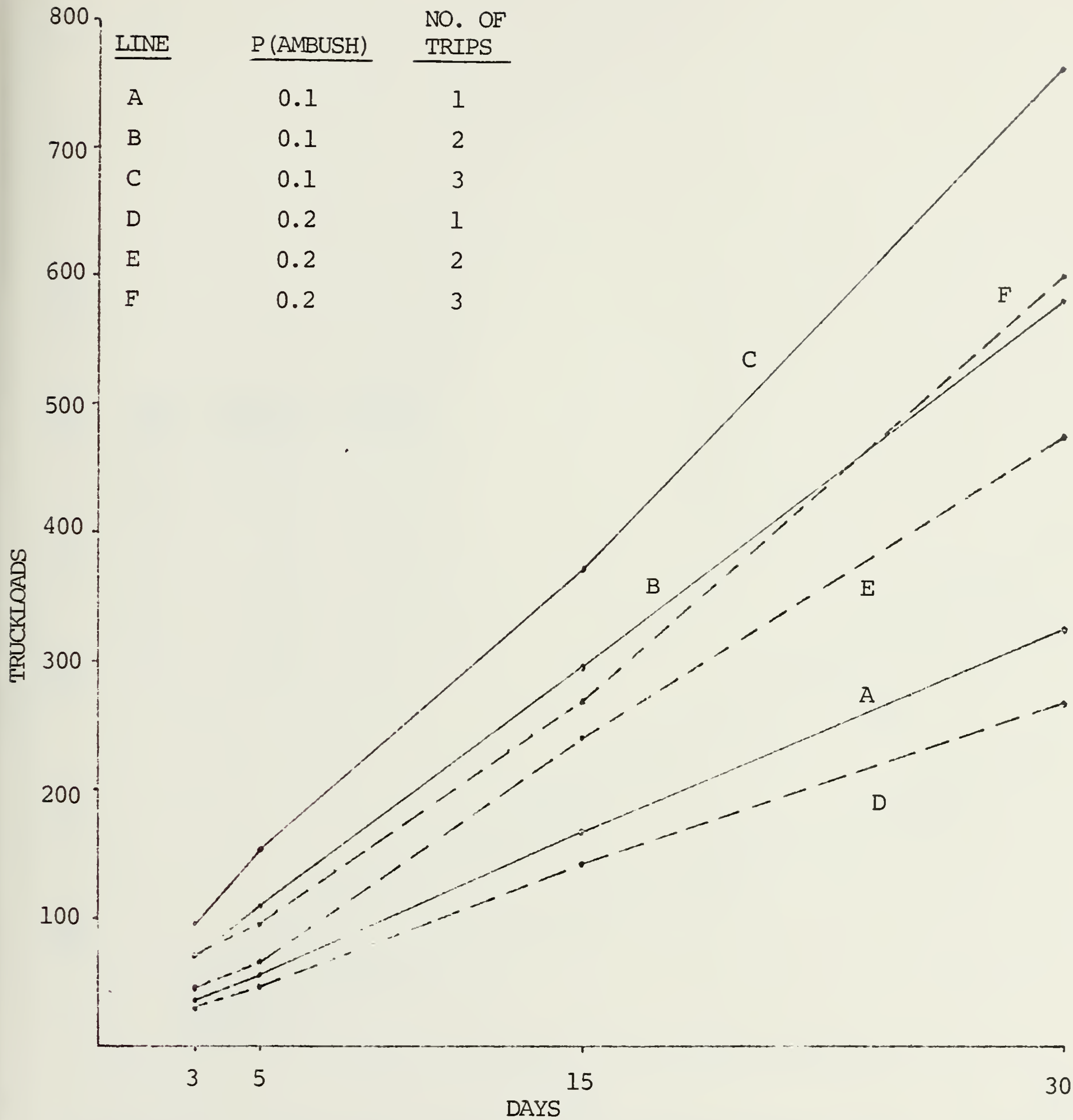


FIGURE 23. Truckloads Delivered for Replacement Time = 3 Days, Max. No. of Vehicles Available = 15

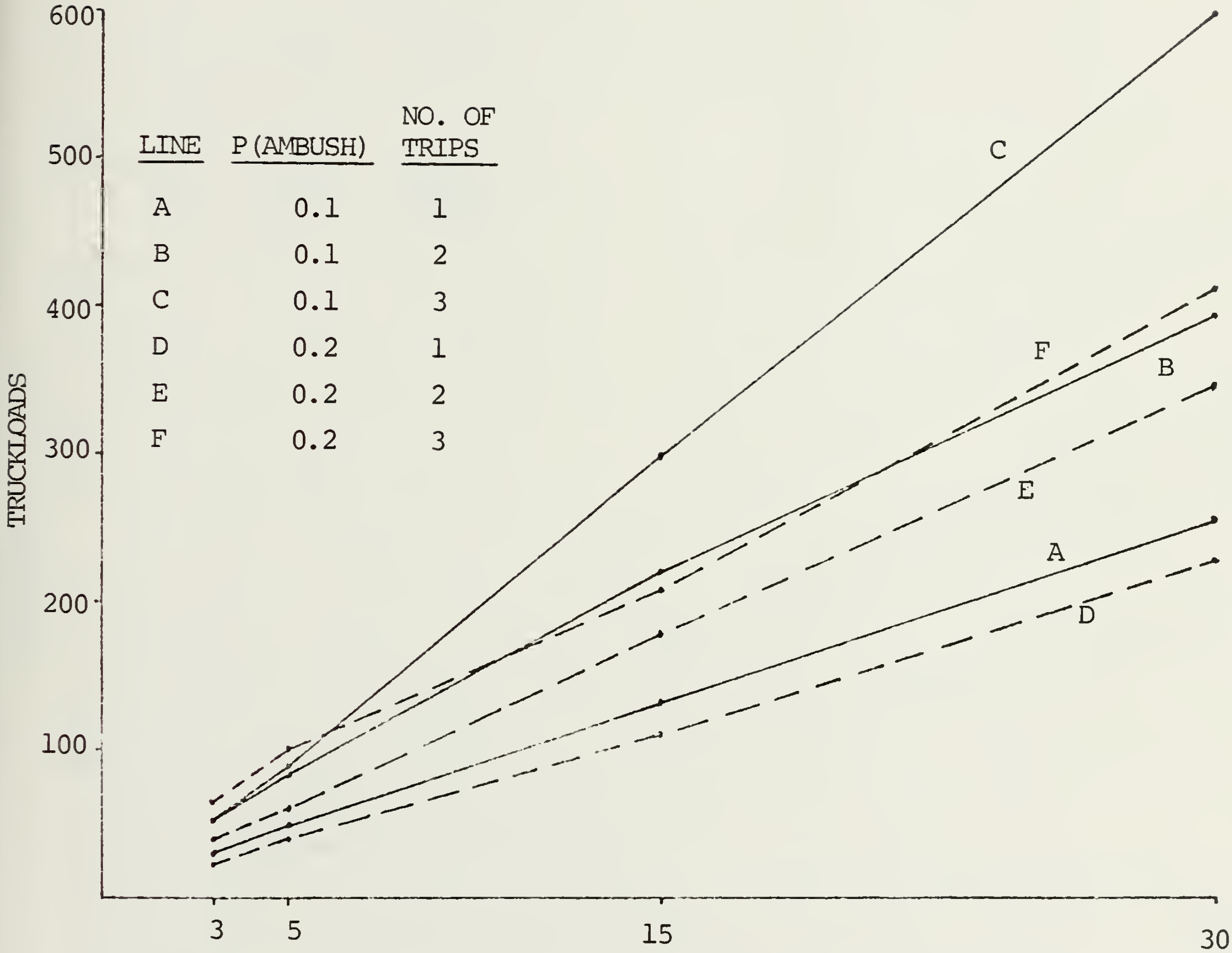


FIGURE 24. Truckloads Delivered for Replacement Time = 3 Days, Max. No. of Vehicles Available = 12

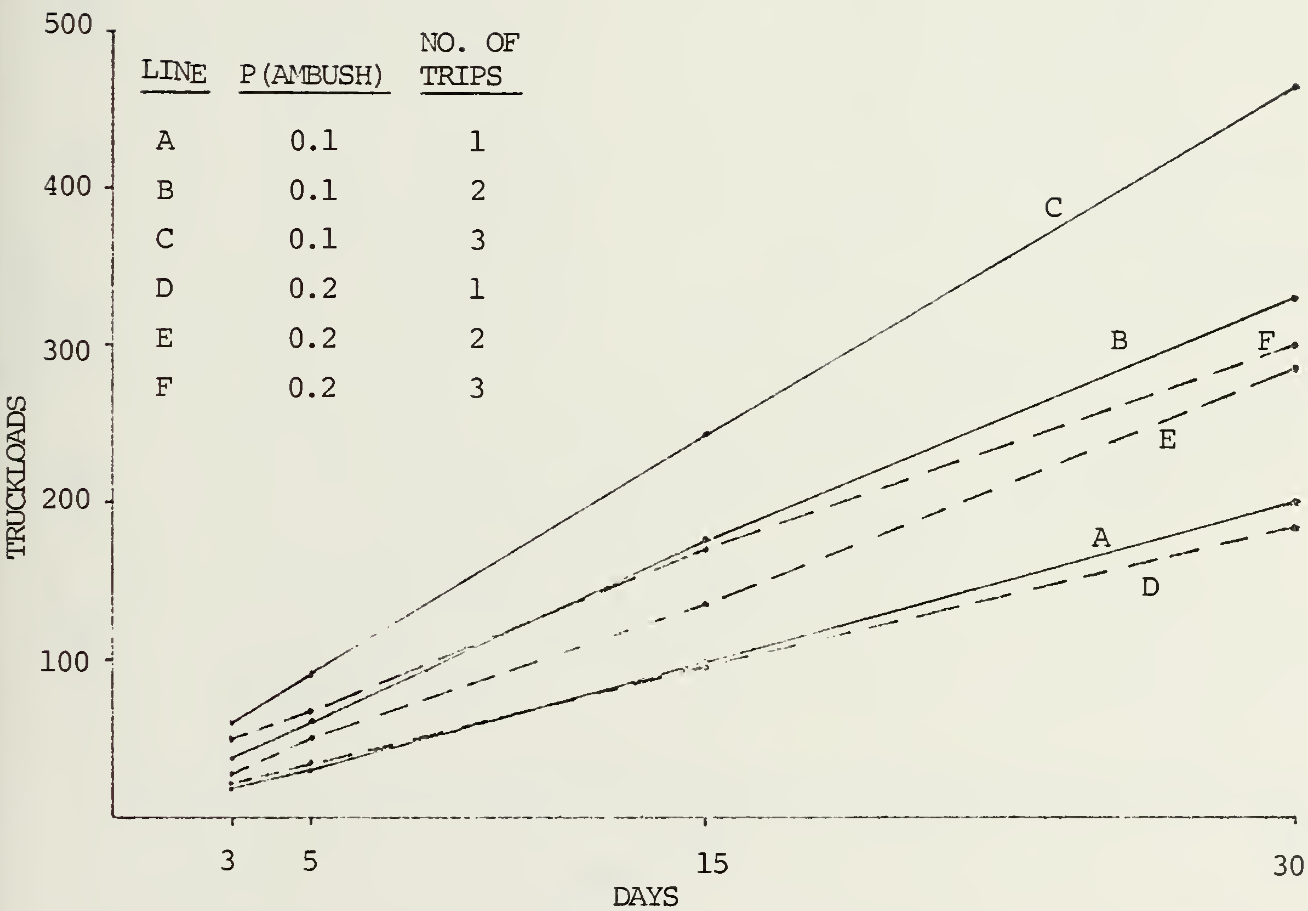


FIGURE 25. Truckloads Delivered for Replacement Time = 3 Days, Max. No. of Vehicles Available = 9

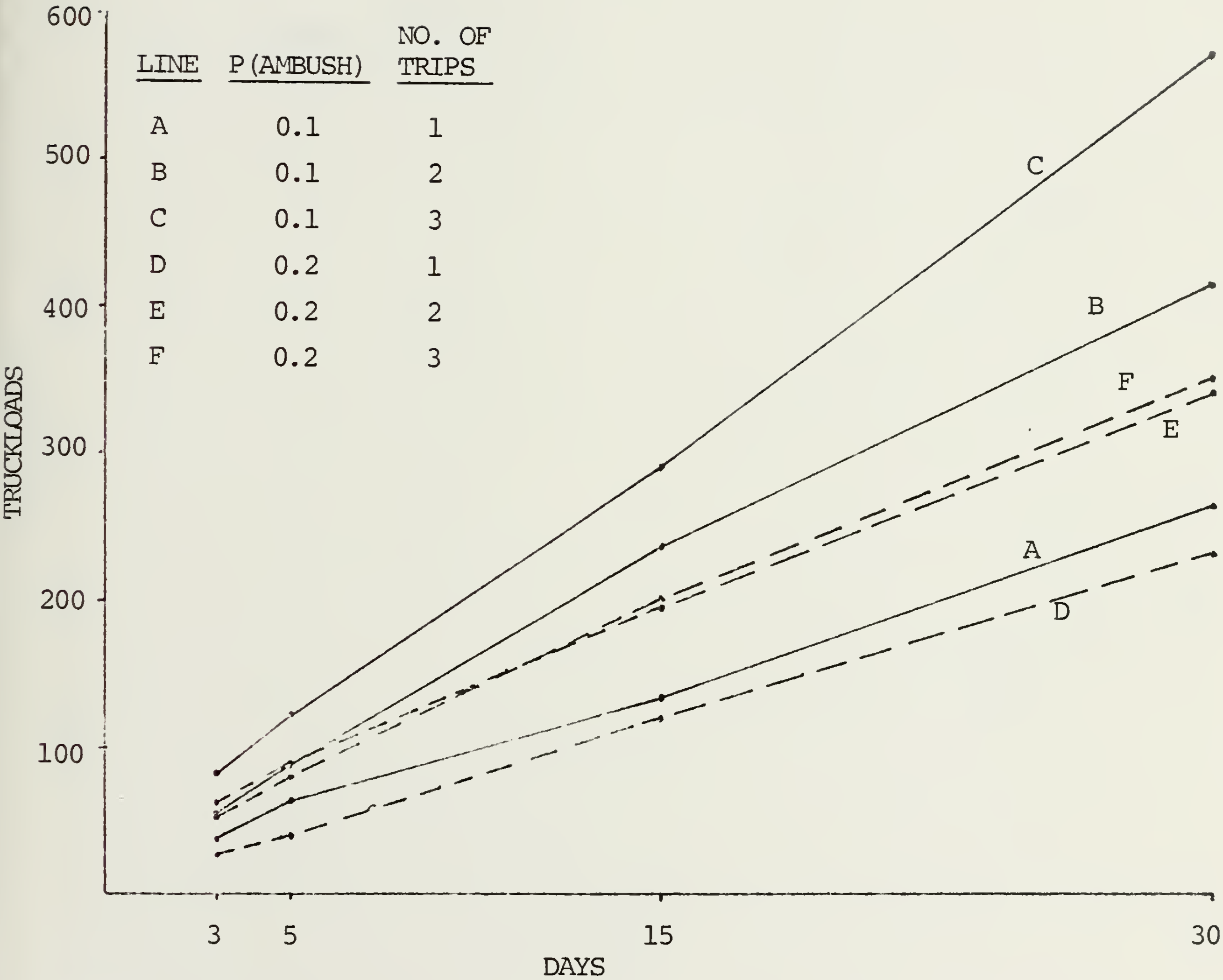


FIGURE 26. Truckloads Delivered for Replacement Time = 8 Days, Max. No. of Vehicles Available = 15

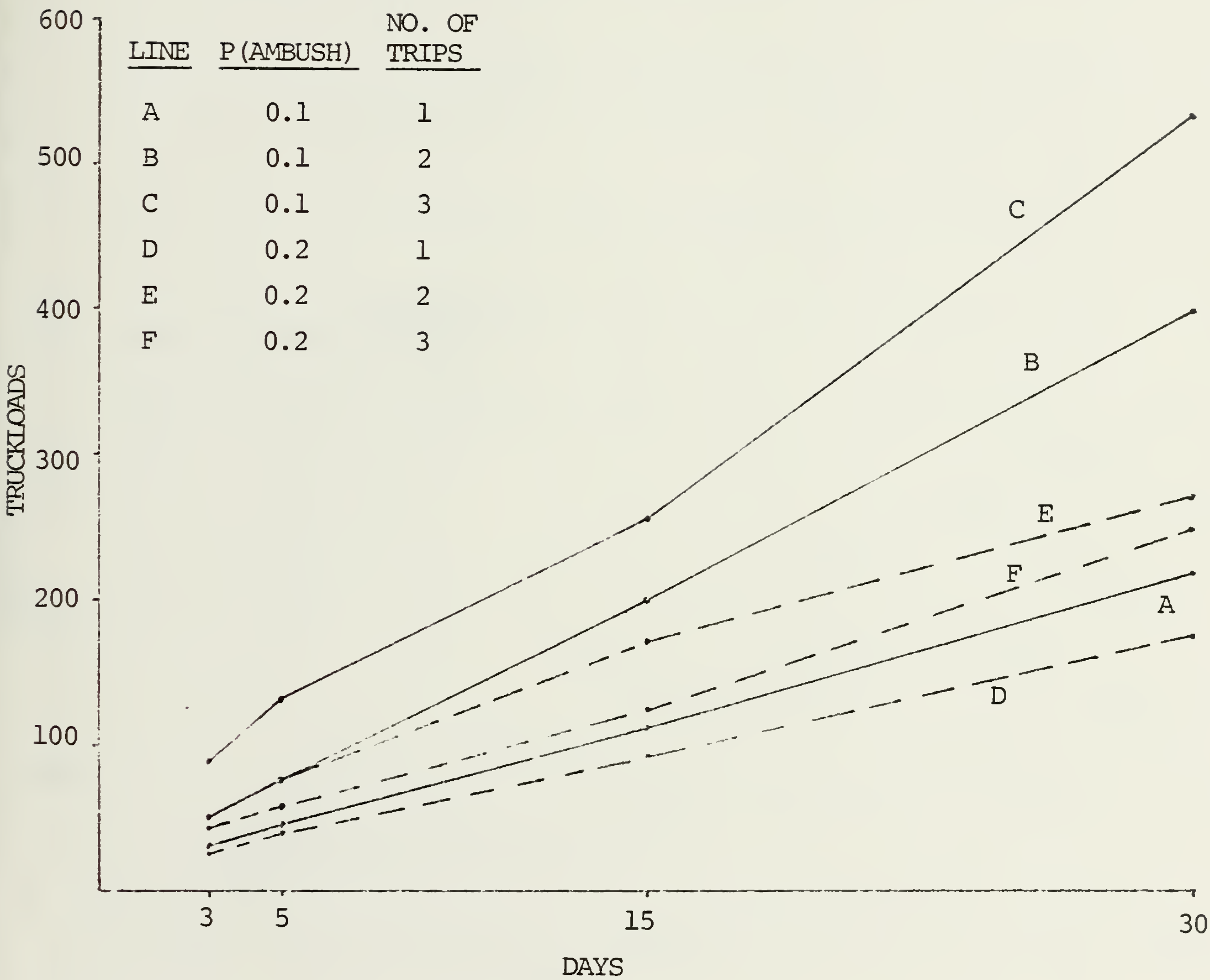


FIGURE 27. Truckloads Delivered for Replacement Time = 8 Days, Max. No. of Vehicles Available = 12

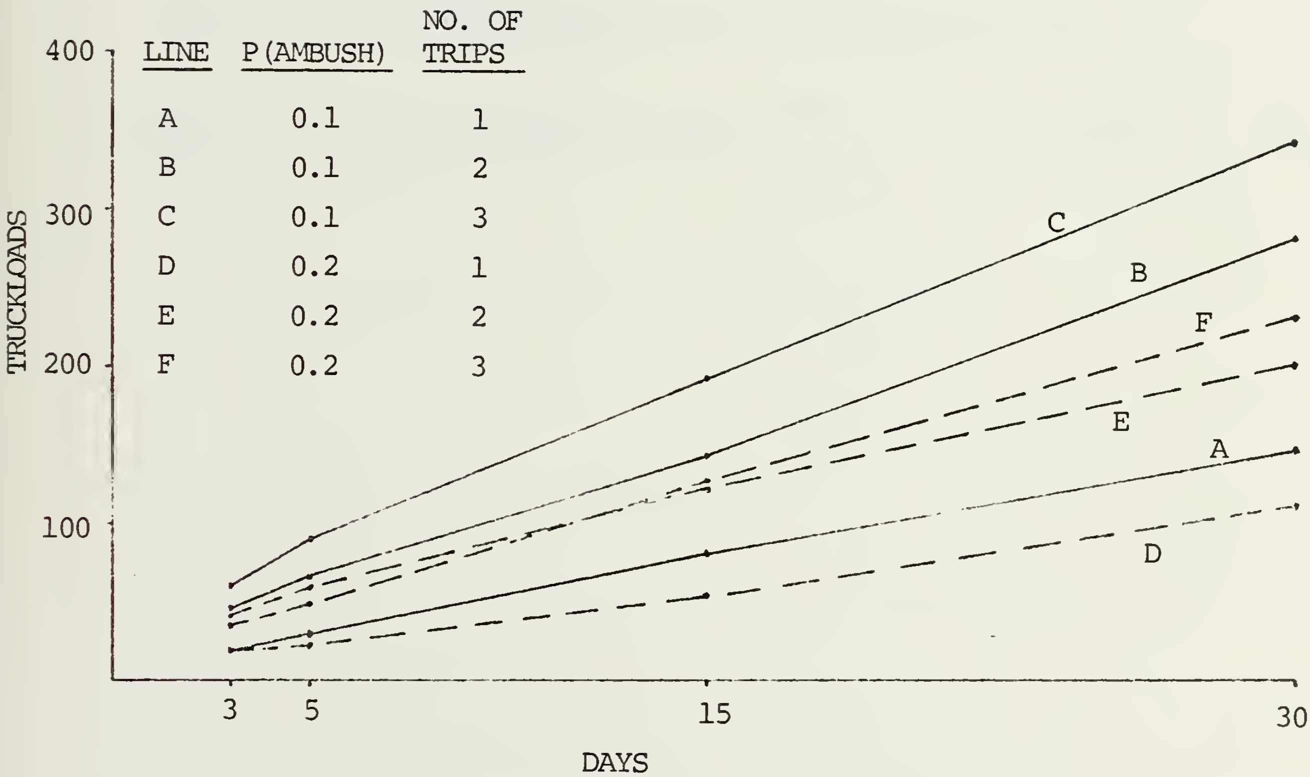


FIGURE 28. Truckloads Delivered for Replacement Time = 8 Days, Max. No. of Vehicles Available = 9

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Simulation and analysis of ammunition transport capability in support of a combat unit.